

# NATIONAL GEOGRAPHIC



## How a Pig Could Save Your Life

The quest to use animals to solve the organ donor crisis

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## Protecting Morocco's Vanishing Oases

The mission to preserve the desert's precious wetlands

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A bold experiment to reimagine how our clothes are made

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PABLO "POPI" GARCIA BORBOROGLU



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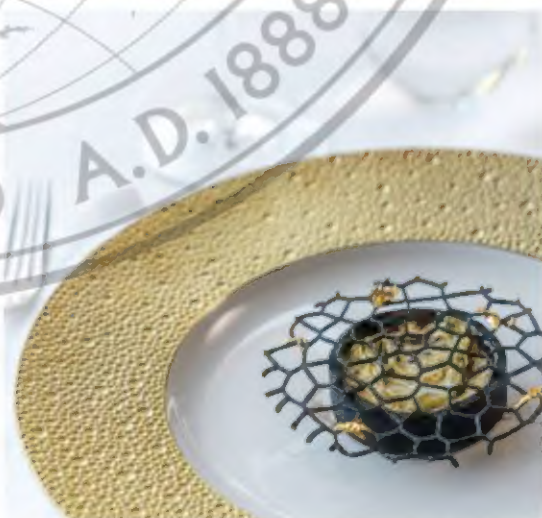
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FROM *the* EDITOR

NATHAN LUMP

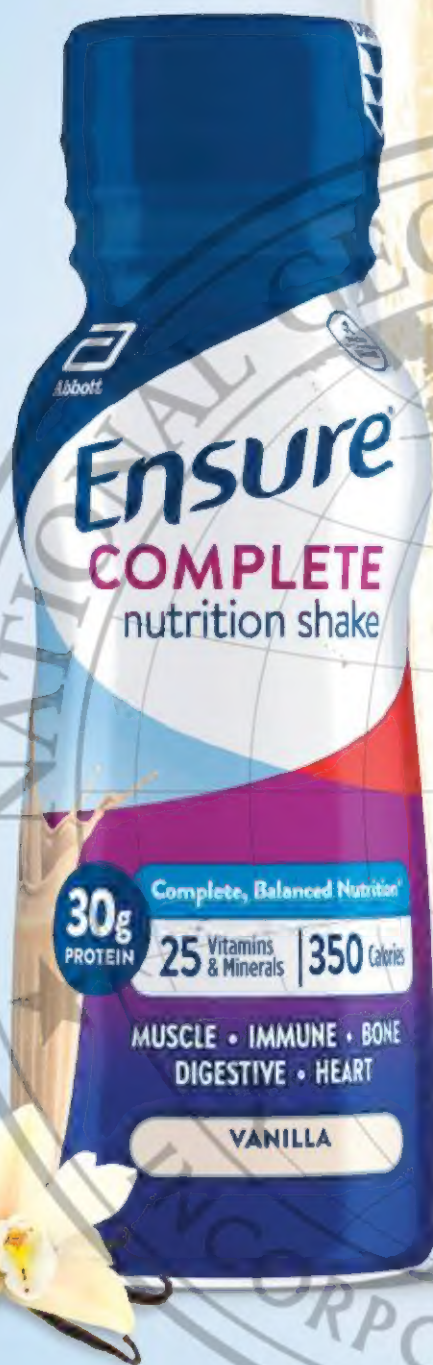
IF YOU, like me, are searching for hopeful stories these days, look no further than this issue's cover feature, which explores the evolving science of xenotransplantation: the transfer of animal material, especially organs, to humans.

While not a new idea, this practice has made remarkable strides in just the past year, thanks to a trifecta of pioneering biotech companies, forward-thinking doctors and their medical institutions, and uncommonly brave patients. Specifically, genetically modified kidneys from pigs have been successfully transplanted into people, raising the promise that there may soon be a new, viable option for the tens of thousands of patients each year in the United States alone who need an organ but cannot find a donor. It's a story that is at once fascinating and emotional and, I promise, well worth a read.

Elsewhere in these pages we have

more features that similarly offer promising solutions to thorny problems. In the western U.S., beavers are being restored to habitats that need them, their dams and ponds helping ecosystems retain water and flourish. We look at a "slow fashion" brand in Indonesia, which is working with local farmers and artisans to develop a more sustainable model for making clothes. And while it is less clear how to save North Africa's oasis towns from the encroaching desert as our planet warms and water supplies dry up, we check in with a community in Morocco, where a combination of age-old wisdom and modern ideas is raising hope that these sanctuaries can be preserved.

I hope you enjoy the issue.



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TO CLOSET**

How one Indonesian entrepreneur, using a regenerative approach to materials and a commitment to ethical labor, is offering a new blueprint for making great clothes.

130 **NEW FROM NATIONAL GEOGRAPHIC**

**ON THE COVER** A genetically engineered piglet huddles in the embrace of a care technician from eGenesis, a biotech firm at the forefront of cross-species organ transplantation.

*Photograph by CRAIG CUTLER*

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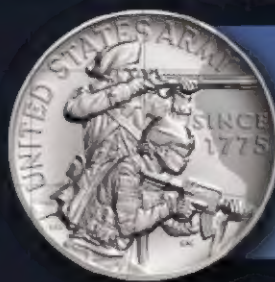
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## IN FOCUS

JUST IN FROM OUR PHOTOGRAPHERS



### LIVELIHOODS

“Strength, freedom, and LOVE FOR THE SEA. Khajoou embodies them all, *floating freely* on the water, looking like she’s not afraid of anything.”

FOROUGH ALAEI, *photographer*

Hengam Island is a rare community in Iran where women fish unaccompanied by men. Its youngest fisherwoman, 26-year-old Khadijeh “Khajoou” Ghodsinejad, began fishing with her mother at around five years old.

# HAVE YOU ROLLED OVER?

If you are at least 70.5 years old, you can transfer up to \$100,000 directly to the **National Geographic Society** from an IRA without paying income tax on the withdrawal—possibly helping to meet your required minimum distribution.



PHOTOGRAPH BY MICHAEL NICHOLS

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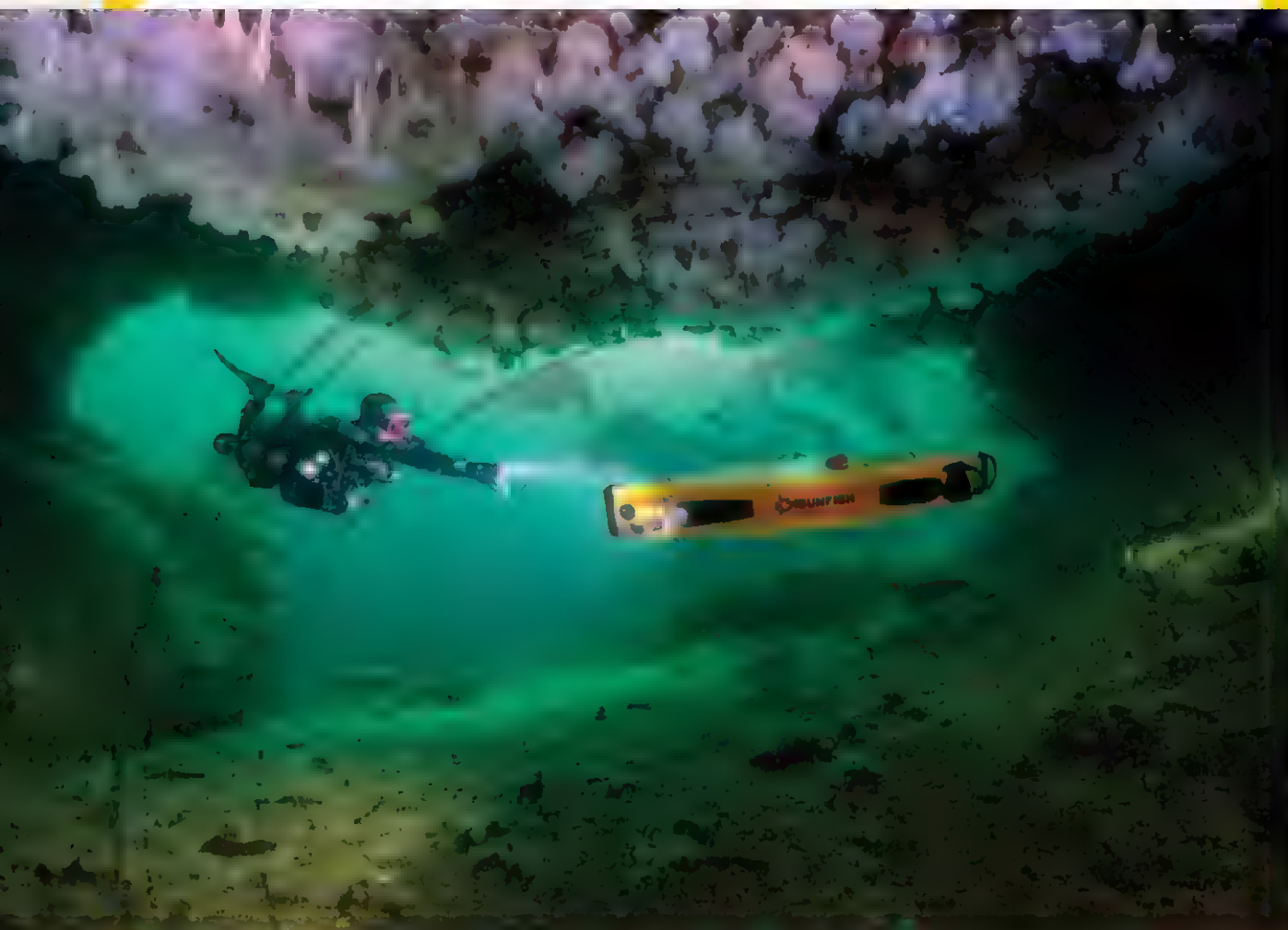
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ARCHAEOLOGY

“When *SUNFISH* found something interesting, it would come back to the boat to *guide the team* back to the spot. It spent the rest of the time as our DIVE BUDDY and *communication link* to the surface.”

JASON GULLEY, *photographer and National Geographic Explorer*

*Sunfish*, an autonomous underwater vehicle, glides alongside diver Tamara Adame off Alaska's Prince of Wales Island, seeking cave sites where humans might have lived tens of thousands of years ago.



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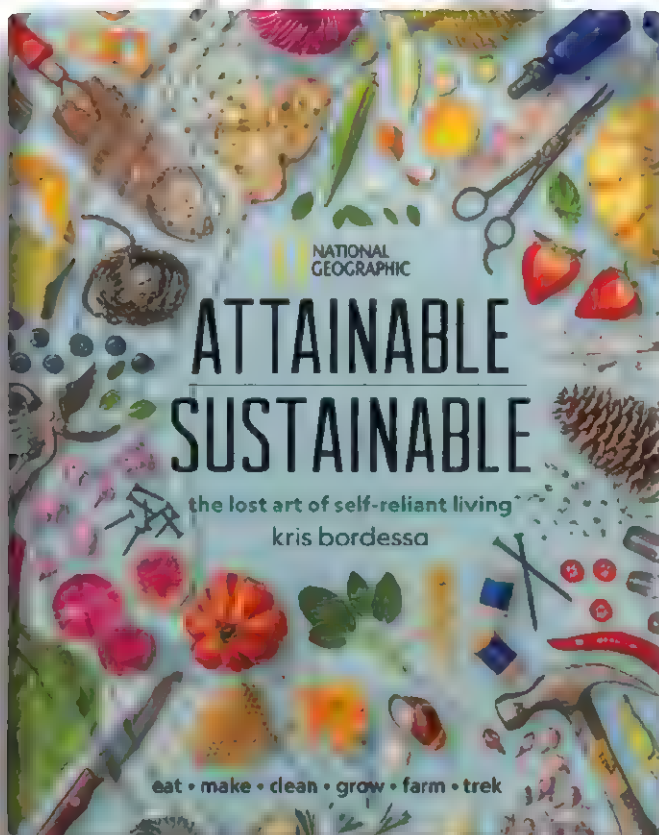
COMMUNITY

“The Friday night rodeos are an AUTHENTIC glimpse of the *rural mountain life* I knew as a kid—from *bull riding* to singing the national anthem to eating cotton candy.”

NATALIE BEHRING, *photographer*

Addie Wright-Clark, age 12, and her miniature horse Splash are festively decked out for the Teton Valley Rodeo in Driggs, Idaho, held weekly all summer long.

# YOUR GO-TO GUIDE TO A WHOLESOME KITCHEN

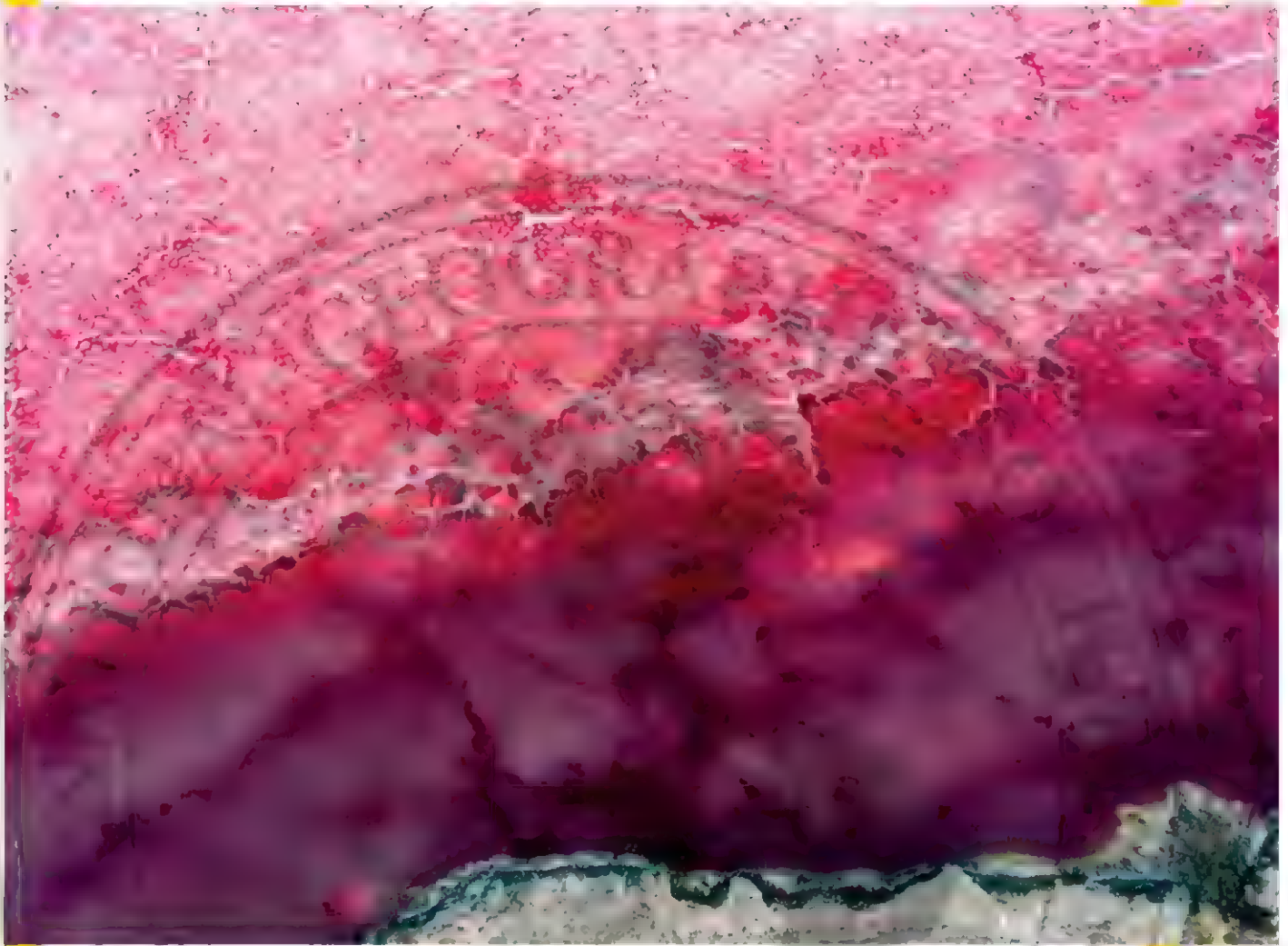


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 NATIONAL  
GEOGRAPHIC



NATURE

“Lake Magadi’s mineral deposits create a *spectacle* of incredible shapes: lacelike spirals, shells, and whirls. But after storms roll in, the formations **VANISH** beneath the water, awaiting their *next transformation*.”

MICHEL AND CHRISTINE DENIS-HUOT, *photographers*

The highly alkaline lake in Kenya’s Great Rift Valley hosts microbes responsible for its striking red and pink hues. When the water evaporates during the dry season, the dissolved minerals crystallize into mesmerizing patterns.



#### SPORT

"I started attending HIGHLAND GAMES with the idea of interrogating what *Scottishness means* for people partaking in them today. However they're celebrated, the games still *bring people together*."

ROBBIE LAWRENCE, *photographer*

To lose at backhold wrestling—a traditional event at Scotland's Highland Games, staged here for a portrait—simply fall or break your hold on your opponent.

## CONTRIBUTORS

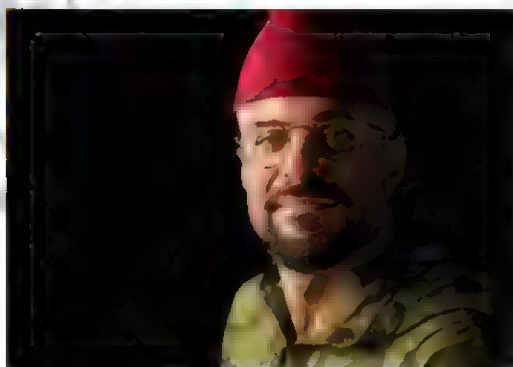
### NATIONAL GEOGRAPHIC EXPLORERS

These contributors have received funding from the National Geographic Society, which is committed to illuminating and protecting the wonder of our world. Learn more about the Society's support of Explorers at [natgeo.com/impact](https://natgeo.com/impact).



**Ronan Donovan,**  
p. 78

To photograph this month's feature on beavers' ecological footprint, Donovan visited landscapes shaped by the underappreciated animals in Idaho, Wyoming, Utah, and his home state of Montana, where he lives in Bozeman. A field biologist by training, he has also shot for *Audubon*, the *New York Times Magazine*, and *Modern Huntsman*.



**M'hammed Kilito,**  
p. 52

An Explorer since 2020, Kilito photographed oases in Morocco and Saudi Arabia for this month's story on the threatened desert areas. Kilito lives in Rabat, Morocco, and his work has been published in the *Atlantic*, *El Pais*, and the *British Journal of Photography*. This is his first story for *National Geographic*.



**Kholood Eid,** p. 78

Based in New York City, Eid photographed biologists and activists across the West for this issue's beaver story.

She is the recipient, with *New York Times* colleagues, of a Robert F. Kennedy Human Rights Journalism Award.



**Muhammad Fadli,**  
p. 106

To photograph the people and processes at the center of our story on sustainable fashion,

Fadli traveled through Indonesia from his home in Jakarta. His photos have appeared in *Time*, *Der Spiegel*, and other publications.



**Tristan McConnell,** p. 52

Based in Woodbridge, England, McConnell reported from Morocco for this month's feature

on troubled oases. His stories have been published in *GQ*, *Emergence*, *Aeon*, *Harper's*, and *Vox*.



**Matthew Shaer,**  
p. 16

A *New York Times Magazine* contributing writer, Atlanta-based Shaer went to the

Midwest and Massachusetts to cover animals as organ donors for his first piece in the magazine.



**Claudia Kalb,** p. 106

For this month's feature on reimagining clothesmaking, Kalb traveled to Java from her home in Alexandria,

Virginia. Her last piece for *National Geographic* explored new ways of caring for people with dementia.

# THIS PIG COULD SAVE YOUR LIFE

For decades, scientists and surgeons around the world have been trying to solve the organ donor crisis. Could the answer be rolling in the mud?


Words by **Matthew Shaer**

Photographs by **Craig Cutler and Joe Carrota**




CRAIG CUTLER



A piglet is shown in a laboratory setting, standing on a red perforated metal grate. The piglet has a white body with a grey patch on its head and a black collar around its neck. A large, faint circular stamp is visible in the background, containing the text "NATIONAL ANTHROPOLOGICAL ARCHIVES" and "WASHINGTON, D.C. 20560".

At a farm and lab in the Midwest, biotechnology company eGenesis is designing, cloning, and raising pigs whose kidneys can be used in human transplant patients. Just two days old, these piglets are kept in a heated space as they find their footing.

©CRAIG CUTLER



**The entry requirements** should have come with an instruction booklet: Sign in at the security hut. Shoes off at the door. Over to the locker room for a hot shower. Into a long protective surgical smock and knee-high rubber waders, and finally, a pair of safety goggles, which—in the clammy heat of the laboratory complex—quickly began to fog.

“Sorry for the trouble,” smiled my tour guide, Björn Petersen, waving me forward. “We just have to be exceptionally careful about pathogens. You’ll get used to it, I promise.”

A couple of hours earlier, I’d awoken in a hotel in a Midwestern city I’ve been asked not to name. Now, with the sun curdling above the surrounding pasture and a gauze of mist in the air, I found myself following Petersen, a German-born scientist, through the corridors of a highly secret research facility and across a muddy courtyard crosshatched with boot prints. “When we bought the place,” he said, “the owners were using it as a livestock research facility.” He indicated an adjacent barn. “The cattle were here, and the horses in the field up there. We’ve kept the same basic layout, though obviously our purpose is very different.”

---

eGenesis scientist Raquel Castro prepares pig cells for the cloning process. The first stages entail using the gene-editing technique CRISPR to modify a cell sample. The modifications ensure the eventual kidney grown in a pig will be accepted by the human patient’s immune system.

CRAIG CUTLER





After the cells have been edited, they are used to generate an embryo that's implanted into the oviduct of a surrogate pig. It will give birth in just under four months to a litter of piglets with two kidneys that may be suitable for transplantation into a human.

CRAIG CUTLER



He said something else as we entered the barn, but I didn't catch it—his voice had been drowned out by a raucous chorus of expectant grunts and the clatter of trotters on cement. A dozen-odd pigs surged forward to the edges of the individual enclosures, clanging their snouts against the metal gates. "I want you to meet someone," Petersen said, blinking into the harsh overhead light. He stopped near the pen of an animal whose name card identified her as Margarita. She curled her body against Petersen's hand, in the manner of an oversize house cat. "Margarita was one of our first," Petersen said proudly, leaning down to stroke the protuberant black hairs between the pig's ears. "Most of these animals you're looking at were created from the same cells. But there's something special about the first, don't you think?"

Petersen, who serves as the site head at the farm, is a specialist in livestock cloning and xenotransplantation—an exceedingly advanced scientific technique in which animal matter is transferred into human patients. (The name derives from the Greek for "strange" or "foreign.") In 2023, after nearly a quarter century working at government research institutions in Europe, Petersen uprooted his family and moved to the Midwest to take a job with eGenesis—a biotech firm backed by a group of venture capital firm investors—then in the early phases of a remarkable plan to develop genetically modified pig kidneys for transplantation into humans. Powered by advances in gene editing and immunosuppressive medicine, eGenesis had quickly demonstrated that its organs could survive for long periods in the bodies of primate test subjects, filtering blood and producing urine as ably as an "allotransplanted," or same-species, kidney.

Now, two years later, Petersen and eGenesis stand at the forefront of a major revolution in the science of organ transplantation—a revolution that will have implications for the global human donor shortage and the thousands of sick patients who wait every year for



a new kidney. Already, the results have been astonishing: a progression from trial transplants on primates to transplant surgery on brain-dead human recipients—and finally, last March, in a development that made global headlines, to a transplant into a living human recipient.

Food and Drug Administration officials have since given eGenesis the green light to conduct a three-patient clinical trial, a move that added to the surging interest the company has generated since last year's historic xenotransplant. Provided it stays on track and its trials prove successful, eGenesis's CEO Mike Curtis says, the company is making plans to grow its production capacity, and he thinks the science could become widely available to the public before the decade is out. "In the long term," he added, "I'd argue we're looking at a scenario where cross-species transplants fully supplant allotransplants. Where we don't need human donors anymore."

Reaching that point will require further refinement of the technology and will demand more pigs like Margarita and scientists like Petersen. But more than anything, it will require trust on the part of those who go under the knife, who put their lives in the hands of this cutting-edge science and the doctors and hospitals championing it. And last year's successful xenotransplant—a four-hour procedure completed at Boston's Massachusetts General Hospital that demanded

untested faith, a hefty dose of desperation, and an unmeasurable amount of luck—was perhaps the most significant step forward into this new future.

And it all started on a farm in the Midwest, where, on a cold March morning, a van idled in the dawn air. Its door slid open, a one-year-old pig was trundled inside, and the vehicle rolled down the drive, carrying what amounted to years of medical research, hope, and investment snorting in the back.

For the next 18 hours, as the van traveled eastward along I-90, a million scenarios raced through Curtis's mind. "You're sitting there, thinking, What if the van gets hit by a car?"

Or what if Rick Slayman changes his mind?

**T**HE ROOM WAS SILENT. All other options had been depleted, and time was slipping away. Sitting at his desk in his office at Massachusetts General Hospital, looking across the room at a man who had become his friend as much as his patient, nephrologist Winfred Williams asked his long-shot question and waited for the response.

"Are you familiar with the term 'xenotransplantation'?"

Rick Slayman, who was running out of vasculature access for dialysis, shook his head. Williams wasn't surprised. At this point, in 2023, xenotransplantation was still a subject relegated to scientific journals and the occasional short news item on skin grafts or corneal transplants. So he did his best to explain that rapid advances in gene editing were offering hope that doctors might soon be able to place a pig kidney inside a human without the risk of acute and immediate rejection. Williams had been talking a lot with the folks at a biotech company across the Charles River called eGenesis. He'd learned that it had recently been granted approval from the FDA for an "expanded access" trial—a special

---

## Abigail Schaefer

*Neonatal care technician*

Schaefer is among the staff at eGenesis's lab and farm in the Midwest tasked with caring for the company's genetically engineered pigs and piglets, from the time they're born to the moment a patient in need is identified.

CRAIG CUTLER

■

**'IN THE LONG TERM,  
I'D ARGUE WE'RE  
LOOKING AT A SCENARIO  
WHERE ... WE DON'T  
NEED HUMAN DONORS  
ANYMORE.'**

**Mike Curtis,**  
*CEO of biotech firm eGenesis*

allowance to treat patients who have no alternative treatments available to them.

Williams did not need to tell Slayman that he qualified. A supervisor with the Massachusetts Department of Transportation and a cheery man with the habit of charming nearly everyone he met, Slayman had struggled all his life with hypertension and diabetes, frequently twinned conditions that had given way to end-stage renal failure: significant destruction to his kidneys and declining function in both. Slayman had been prescribed a course of dialysis, but as Williams later recalled, the treatment had quickly become intensely time-consuming for his medical team and excruciatingly painful for Slayman. "For dialysis to work properly," Williams told me, "you need to have reliable vascular access." Traditionally, that access is secured via an arteriovenous fistula, a surgical connection between an artery and a vein and perforated by a pair of needles. One needle removes the patient's blood; the other channels back a "cleaned" version. "The problem in Mr. Slayman's case," Williams said, "is that he was experiencing significant blood clotting, and it made it difficult to get a continuous flow going during dialysis. In a given year, he was undergoing multiple declotting sessions at a hospital. Back and forth, back and forth."

It was a hard way for anyone to live, let

alone someone as naturally energetic as Slayman. And the long-term prognosis was grim, Williams knew. Effective dialysis does not reverse damage to the kidneys. It simply makes it possible for a patient to continue living. In the end, a transplant is required, provided an organ can be located: In 2018, of the roughly 95,000 Americans waiting for a new kidney, only 25 percent managed to obtain one.

That December, Slayman had become one of the lucky 25 percent. His surgery, performed by a veteran Massachusetts General surgeon, Tatsuo Kawai, was frictionless, the postsurgery complications apparently minimal. Slayman was able to go back to work full-time. But within three years, familiar symptoms started to reappear: the swelling, the fatigue. Tests revealed scarring on the donor kidney and early evidence of recurrent diabetes. "It was clear to me," Williams told me, "that the organ wasn't going to survive for many more years."

Once again, Slayman found himself thrust into a punishing cycle of dialysis and declotting; later, doctors started him on a course of anticoagulants and installed a new fistula on his upper thigh. Nothing seemed to help. Instead, more worrying signs emerged, like hyperkalemia, or abnormally high potassium levels, which left Slayman breathless and sent him racing to the local emergency room for treatment.

"He had to undergo a lot of interventions that required anesthesia and long hospital stays, and I remember him saying, 'Doctor,

---

**Violet**

At six months old, Violet is one of eGenesis's patient-ready pigs. The company uses the Yucatan miniature breed, as its organs are naturally similar in size to those of humans.

CRAIG CUTLER



# HOW TO DESIGN A LIFESAVING KIDNEY

Placing a pig's kidney inside a human patient is more complicated than merely swapping one organ for another. For the biotechnology company eGenesis, the process begins by genetically modifying the embryo of a Yucatan pig so it will grow kidneys that will be accepted by the human body. Here's how it's done.

Graphic by JASON REA

1

## Evaluate a tissue sample

A specimen from the ear of a Yucatan pig is carefully reviewed, or sequenced, to ensure there are no issues that will interfere with the gene-editing process.

3

## Make it more human

Scientists then insert seven human samples DNA that will protect kidney from inflammation, cell death, coagulation—and also trick the host system into accepting the foreign

CD46 and CD55 protect porcine cells and prevent them from being damaged by the human immune system

CD46

CD55

## Cornea

With thickness and elasticity similar to a human's, a porcine cornea can be used to replace a diseased cornea, correcting sight or reversing blindness

Porcine-endogenous retrovirus (PERV) is a viral gene found in all pigs and may cause disease and tumors in humans

PERV

B4GALNT2

This gene creates an antigen on the cell surface that human immune systems attack immediately

GM1A

This gene produces a protein adjacent acid that humans cannot synthesize—if the donor kidney contained it, the organ would be rejected

GGTA1

This gene must be deleted as it creates an antigen called alpha gal, which the human immune system rejects and destroys.

2

## Delete problematic pig genes

Using the gene-editing technology CRISPR, eGenesis scientists must alter the tissue sample to prevent the spread of viral disease and potential organ rejection. That means removing four pig-specific genes.

## BEYOND KIDNEYS

Pigs are ideal candidates for xenotransplantation because their organs are similar in size to ours and have a similar anatomy and function. Research is under way to determine which body parts from pigs could be most useful to humans.

an genes into  
ct the future  
amage, and  
human immune  
n organ.

Key to reducing  
inflammation, THBD  
and PROC1 create  
proteins that also  
help with preventing  
blood clotting

TNFAIP3 and HMOX1  
identify the pig cells  
is healthy so they  
will not be removed  
by the human  
immune system

CD47 receptor  
a protein that  
signals to the  
immune system "Don't eat  
me" - human

**4** **Insert the modified DNA**  
The edited DNA is then fused  
with the nuclei of fetal pig cells.  
Scientists implant these develop-  
ing embryos into a sow that will  
give birth to piglets capable of  
growing human-ready kidneys.

Editing  
DNA with CRISPR

Cells are  
from blastocyst,  
which is then  
implanted in sow

**Kidneys**  
Pig kidneys transplanted  
into humans filter blood,  
balance electrolytes and  
tolerate a human diet.  
The first kidney trans-  
plant from pig to living  
human occurred in 2024

**Lungs**  
Lungs are more challeng-  
ing for xenotransplan-  
tation, as the vast surface  
area of tissue offers more  
opportunities for infection,  
but research is ongoing

**Heart**  
In 2022 a porcine  
heart was success-  
fully transplanted  
into a human for  
the first time.

**Liver**  
While human and pig  
livers share a common  
structure, ongoing  
questions about the  
compatibility of cer-  
tain liver proteins in  
pigs have held up any  
major advances

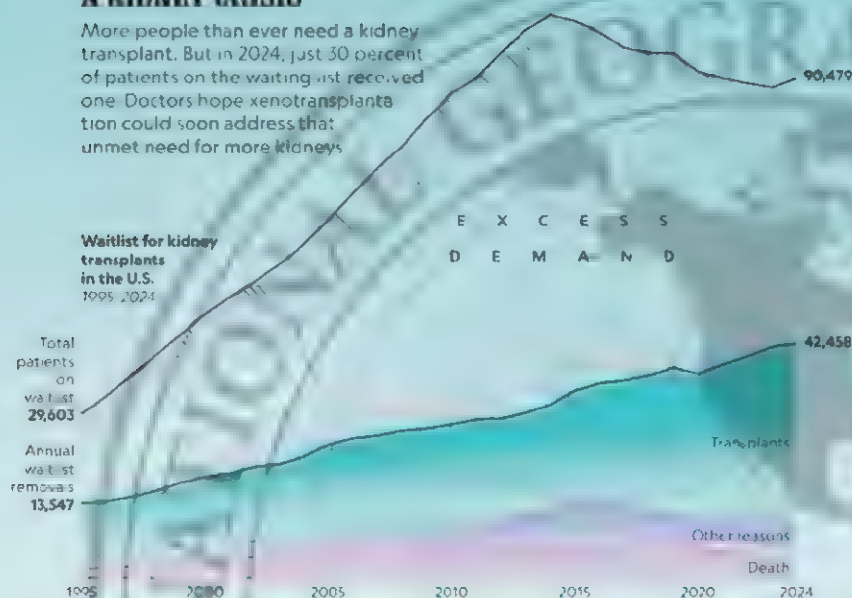
**Pancreatic islets**  
Clinical trials are under-  
way to transplant  
these pancreatic pig  
cells, which produce  
insulin and could help  
treat type 1 diabetes

**5** **Harvest the organ and  
transplant into patient**  
Once the piglets reach maturity,  
their kidneys can be harvested  
and prepared for transplant.  
After surgery, patients must still  
take immunosuppressive drugs  
to prevent organ rejection.

REPORT BY DR. JENNIFER L. FORD AND JENNIFER L. FORD  
RESEARCHER, UNIVERSITY OF TEXAS AT AUSTIN  
PHOTO: AP/WIDEWORLD; ILLUSTRATION: ALAN PAX; ART AND APARTHA  
KADAVARTI; ILLUSTRATION: FOR ORGANS, HARN

## A KIDNEY CRISIS

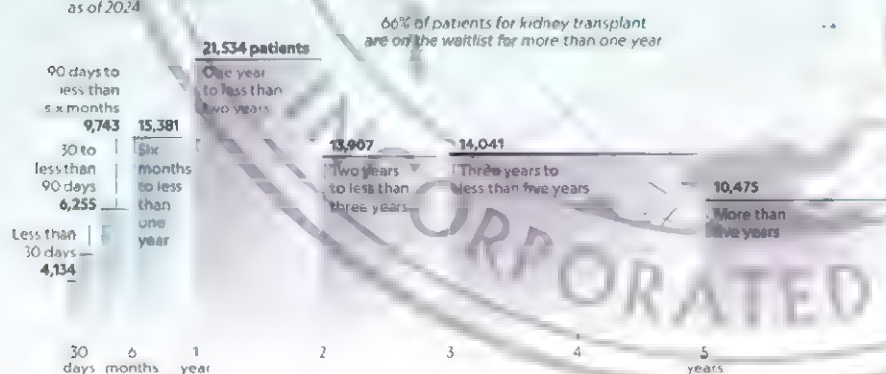
More people than ever need a kidney transplant. But in 2024, just 30 percent of patients on the waiting list received one. Doctors hope xenotransplantation could soon address that unmet need for more kidneys.



## AN ENDLESS WAIT

Patients who are unable to immediately receive a kidney from a human donor are often required to go through painful and tiring dialysis treatments to stay alive.

**Time spent on waitlist for a kidney transplant as of 2024**



### Rick Slayman

#### Transplant patient

A father of two and former employee at the Massachusetts Department of Transportation, Slayman was the first living patient in the world to receive a genetically modified pig kidney, in March 2024.

MICHELLE ROSE



**'MR. SLAYMAN WAS ABOUT TO EMBARK ON A TRIP THROUGH TRULY UNCHARTED WATERS. I COULD NAVIGATE, BUT HE WAS GOING TO HAVE TO BE THE PIONEER.'**

**Winfred Williams**

**Winfred Williams**  
*Transplant nephrologist*

At Massachusetts General Hospital in Boston, Williams treated Slayman for end-stage renal failure, which required frequent dialysis. Slayman's body had already rejected a human kidney transplant. Williams suggested his patient could be a candidate for xenotransplantation.

CRAIG CUTLER

## ALTHOUGH IT FEELS CUTTING-EDGE TODAY, THE SCIENCE OF KIDNEY XENOTRANSPLANTATION STRETCHES BACK DECADES.

I'm not sure I can go on like this," Williams told me. "He was considering withdrawing completely from dialysis. And we knew that would have been a death sentence."

Which brought Williams to the idea of xenotransplantation and his conversations with eGenesis. Williams trusted the scientists at the company; he'd visited their labs himself and had marveled at what he saw there. Still, he knew his patient would likely have reservations. Like Slayman, Williams is Black, and his mind went instantly to the infamous Tuskegee experiments, in which the U.S. government conducted a 40-year study of hundreds of Black men with syphilis but intentionally hid their diagnoses and withheld treatment via penicillin when it became available. "You have to understand that what happened at Tuskegee is hardwired in African Americans in the U.S.," Williams said. "It has created deep fear about being used as a guinea pig."

Over the course of several informed consent meetings, Williams was as clear with Slayman about the hazards of undergoing a cutting-edge procedure as he had been about the hazards of doing nothing at all. It would not be easy. He would have to be brave. But Slayman said he understood. In conversations with his family, his daughter Pia Slayman later recalled, her father was "confident about how much of a success the

surgery would be. So I couldn't do anything but support him."

The last informed consent session occurred in early 2024, shortly before the transplant surgery was scheduled to take place. Williams told me that halfway through, Slayman burst into tears. "He said, 'I want to do this, but I want you to be there for me. To take care of me.' And I promised I would. It was such a poignant moment, because Mr. Slayman was about to embark on a trip through truly uncharted waters. I could navigate, but he was going to have to be the pioneer."

**A**LTHOUGH IT FEELS cutting-edge today, the science of kidney xenotransplantation stretches back decades and originated in part with the work of a gifted Tulane University doctor and professor named Keith Reemtsma. In the early 1960s, Reemtsma, a cardiothoracic surgeon by training, began planning a series of animal-to-human surgeries involving kidneys taken from laboratory chimpanzees. The idea was not unprecedented: For decades, scientists had been transfusing animal blood into—or grafting animal skin onto—human patients. The kidney, and the use of immunosuppressants in the human recipients, would merely represent a step-up in scale and complexity. A few years later, Reemtsma was vindicated when one of his patients survived approximately nine months with a chimpanzee kidney—a promising feat in an era when the stakes for patients with failing kidneys were even higher than they are today. There was no widespread access to dialysis treatment, and there was no national donor database for kidney transplants.

The euphoria was short-lived. In the 1960s, kidney disease had already reached crisis scale in the United States, and even if xenotransplantation could be perfected—a big if, considering 12 of Reemtsma's 13 patients

lasted no more than eight weeks on the chimpanzee organs—how could scientists possibly secure enough primates? A hard-to-come-by solution simply didn't make sense, says Robert Montgomery, a transplant specialist at New York University Langone Health and himself the recipient of a donor heart. You also had the animal welfare angle: "People like Jane Goodall have added so much to our understanding of how similar we are to primates," he said.

Finally, Montgomery added, there was the arrival of AIDS, which is believed to have originated in apes. "Having a donor species that is closer to humans on an evolutionary scale is going to make it easier to get a good result," Montgomery told me. "But by the same token, it's also easier to pass a pathogen from a primate to a human" than it would be with another animal.

Like, say, a pig.

Despite being notably intelligent creatures, pigs tend not to be viewed with any particular reverence by most people, E.B. White notwithstanding: By one estimate, more than a billion of the creatures are slaughtered and eaten by humans every year. And pigs breed with alacrity, typically twice a year and sometimes three, with litters averaging eight to 12 piglets. This is one of the reasons that, beginning in the 1990s, many researchers in the xeno field began to gravitate away from primates.

But the shift presented its own unique obstacles, the most vexing of which was represented by a porcine antigen known as galactose oligosaccharide, or alpha-gal for short. This antigen, found in pigs, is not present in the human body, which will attempt to rid it from the bloodstream by producing antibodies that bind to the antigen. When this occurs after an organ transplant, it usually prompts the acute rejection of the donor organ. Antibiotics and immunosuppressants can help but not in the long term, as waves of researchers reluctantly concluded. They realized they'd need to remove the alpha-gal antigen from the pig kidney, a time-consuming process.

An efficient solution to that issue was pioneered in 2012, when scientists Emmanuelle Charpentier and Jennifer A. Doudna patented a technology known as CRISPR-Cas9—an oft-used simile likens it to "a pair of molecular scissors." With CRISPR, researchers made "cuts" in human and animal genetic code, thus replacing disease-causing mutations and fundamentally changing the way genes were expressed.

In the U.S. and Europe, any experimental intervention must pass through two stages before it is made publicly available. In the preclinical stage, a drug or surgery is tested in the lab; in the second, providing the results are acceptable to regulators, researchers can move on to humans.

In 2017, a year before Rick Slayman received a human donor kidney, scientists affiliated with eGenesis opened a preclinical trial on several long-tailed macaques that were outfitted with lab-modified pig kidneys informally dubbed "knockouts"—a nod to the antigens removed via the gene-editing process. One monkey lived nearly 300 days.

"We had a meeting with the FDA, and we basically asked, 'What would you need to see in order for us to move [to the next stage]?' " recalled eGenesis CEO Curtis. "They gave us a figure of 12 months' survival in a monkey. I was like, 'Well, look, we're clearly moving in the right direction.' "

But eGenesis was not alone in its pursuit of FDA approval. Revivicor, a subsidiary of the biotech firm United Therapeutics, had simultaneously been working on its own modified porcine kidneys. At a high level, the engineering methods employed by eGenesis and United Therapeutics, which is publicly traded and designated as a public benefit corporation, appear remarkably similar. Scientists at each company start by editing porcine fetal cells to remove the expression of dangerous antigens before cloning the cells via nuclear transfer—a technique that yields embryos of matching genetic composition. Healthy embryos are then implanted into female pigs,



which give birth to litters of piglets with identically edited cells.

But there the resemblances in approach end. United Therapeutics for its part knocks out just four porcine genes, preferring to utilize a breed of pig, the Landrace, for its fertility and litter size. Conversely, eGenesis makes 69 different edits to its cells, 62 of which are knockouts and seven of which are additions from the human genome. And those cells are different in origin: eGenesis favors relying on the smaller Yucatan pig breed, whose organs more closely match a human's in size.

In September 2021, NYU Langone was granted permission by regulators to transplant a United Therapeutics-edited pig kidney into a brain-dead human patient. (As a brain-dead patient is considered legally dead, the body would be supported by a ventilator during the procedure.) Montgomery, of NYU Langone, was tasked with carrying out the surgery. "I have spent most of my career trying to increase the number of living organ donors," Montgomery told me, noting that the annual number of living human kidney donors has been a flat line for 15 years, hovering at 6,000. "It was hard not to see the transplant as a breakthrough. You could sense the enthusiasm. I felt it too."

In October of 2021, NYU Langone went public with the news: The xenotransplanted kidney had been attached by a network of blood vessels to the patient's upper leg, where it started to function immediately,

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**Robert Montgomery**  
*Transplant specialist*

Montgomery and his team at New York University Langone performed the first ever xenotransplant of a modified pig kidney in 2021, when they transplanted an organ provided by Revivicor, a subsidiary of biotech company United Therapeutics, into a brain-dead patient.

CRAIG CUTLER

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**Robert Montgomery**

creating urine for nearly three days.

Just one major step remained: a test on a living patient.

**W**ITHIN HOURS OF Slayman's final informed consent meeting at Winfred Williams's office, gears began turning at the eGenesis farming facility.

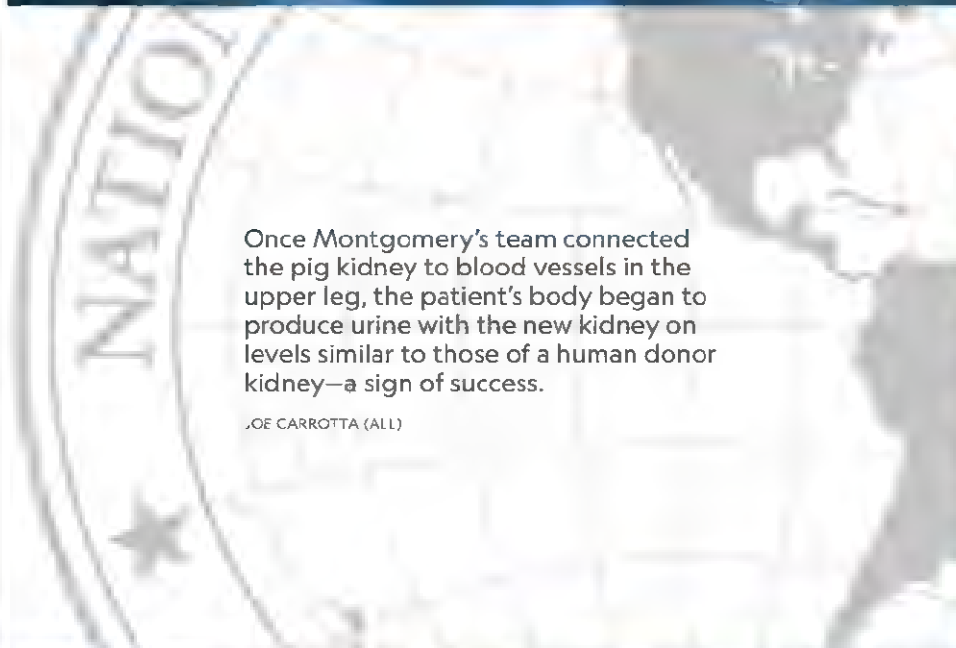
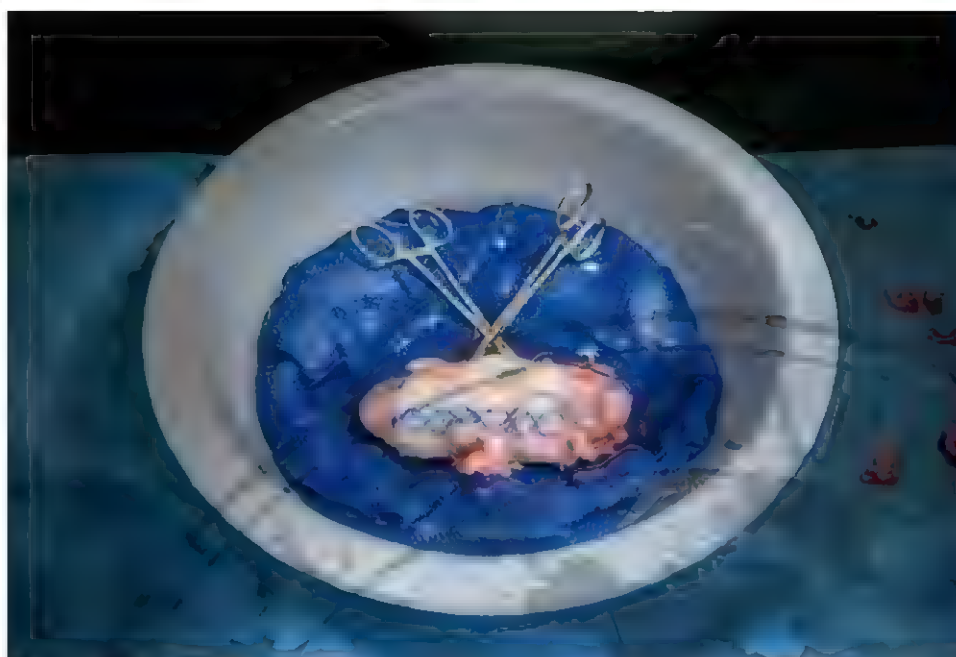
As Björn Petersen watched, the small pig was loaded into the van, which raced down the road and onto the freeway. The ensuing cross-country journey was a "whole logistical dance," Mike Curtis told me. Traveling east through the night, the pig reached a veterinary center in western Massachusetts. There, both its kidneys were removed by Slayman's surgical team, with euthanasia administered postprocurement. By noon, the organs were packed into a refrigerated box and placed in the back of a different truck, pointed this time toward Boston. At Mass General, Slayman—who had already been prescribed a strong course of immunosuppressants—was put under and prepped for surgery while his family waited anxiously in the waiting area. At 1 p.m., on March 16, the procedure commenced.



Montgomery (center) prepares to attach the kidney on the outside of the brain-dead patient's body, allowing doctors to monitor its immediate ability to function.

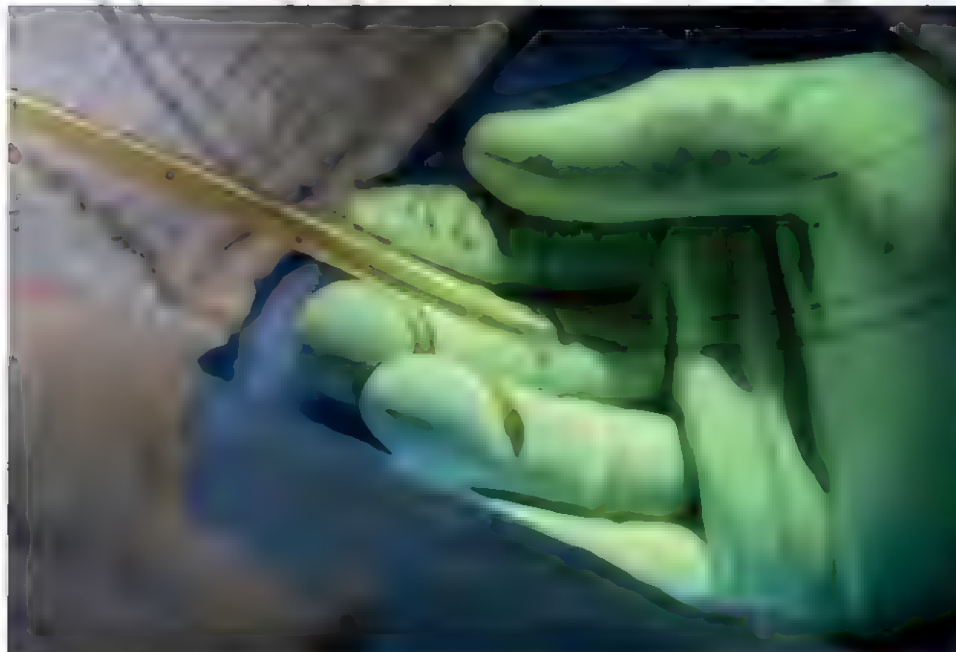
JOE CARROTTA

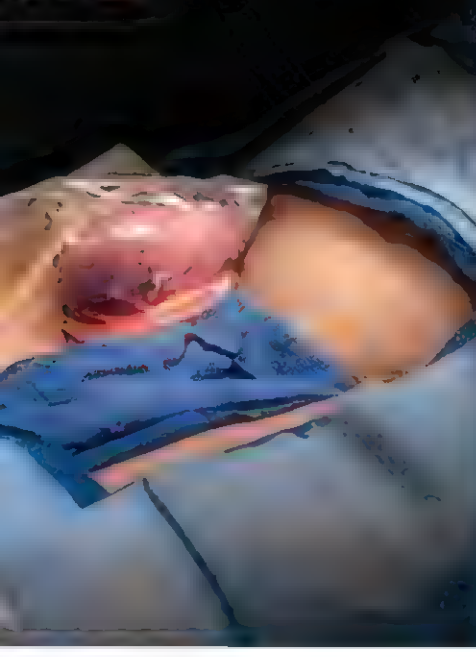




Once Montgomery's team connected the pig kidney to blood vessels in the upper leg, the patient's body began to produce urine with the new kidney on levels similar to those of a human donor kidney—a sign of success.

JOE CARROTTA (ALL)





## 'HE'LL GO DOWN IN THE PANTHEON OF MEDICAL HISTORY.'

**Winfred Williams**

*to Rick Slayman's friends  
and family*

From his position in the operating theater, Williams watched as colleagues Leonardo Riella, Mass General's medical director of kidney transplantation; Tatsuo Kawai, who'd performed Slayman's original kidney transplant years earlier and had worked with Riella to coordinate the FDA approvals; and Nahel Elias, surgical director of kidney transplantation, carried out the procedure. They all knew the difficulties that Slayman's long struggle with kidney disease and hypertension would present. "His whole vascular anatomy had changed," Williams said. "He had very calcified, very hardened vessels, and you can't just crack open calcified vessels and make them work. You've got to find the right anatomic distribution. Plus, you need to remember that Mr. Slayman was a big guy, and the vessels that were available for attachment to the donor kidney were sort of deep within his abdominal cavity."

In the days leading up to the operation, Pia Slayman reminded herself how confident her father had been that the surgery would be a success. When she entered the recovery suite that evening, she took her father by the hand and wept with relief. Although he grasped the history-making meaning of the procedure and the interest it would inspire in reporters, Slayman told hospital staff he'd prefer to stay out of the limelight; gamely, he agreed to pose for a few photos with his family before returning to the house that he shared with his fiancée, Faren Woolery.

The following week was hard: Within a

few days of the surgery, Slayman was diagnosed with symptoms of acute rejection and treated with what Williams described as the same antirejection medication "we would use in a garden-variety human transplant." The treatment was effective.

But 51 days posttransplant, Slayman returned once more for an appointment with Kawai and Riella. The doctors noticed signs of volume depletion—he was losing more nutrients and fluid than he was taking in. Slayman was hooked up to an IV to boost fluid volume, Williams told me, "and he had a magnesium infusion to address some low levels."

That same day, Slayman and Woolery left Mass General and picked up groceries near their home in the Massachusetts town of Weymouth. They made stops at two stores. Slayman accompanied his fiancée into the first one but begged off when it came to the second. He didn't feel up to it, he told Woolery. That night, after eating dinner and watching television together, the couple went to lie down. In the bedroom, Woolery noticed Slayman's breathing had grown labored and shallow around 11:30 p.m. Around midnight, Slayman went into cardiac arrest. Woolery called 911, then dialed Williams, who told the EMT crew by phone to take Slayman to the nearest emergency room. Williams rushed to meet them at South Shore Hospital, in Weymouth, but their combined efforts at resuscitation came up short—Slayman passed away in the early morning of May 11, at the age of 62.

In the hours after Slayman's death, his family huddled with Williams at South Shore for a debriefing. Slayman's brother and fiancée were on hand. Williams explained that it was critical to understand what had happened to Slayman, given his relatively healthy status earlier in the day. After making a call to Slayman's mother, the family granted permission for an autopsy. The results, which were published earlier this year, revealed that the issue had been Slayman's heart, not the kidney.

"What we think happened," Williams said, "is that because of his severe cardiac

disease, he had arrhythmia, and he suffered an arrhythmic event that led to his death.”

The tissue of the kidney was healthy, and although there was “residual evidence” of the initial rejection symptoms, “there was no acute kidney failure that would have been cause for Mr. Slayman’s demise,” Williams said. “Bottom line is that the xenograft was functioning reasonably well.”

It can be difficult to see it that way, of course, given that recipients of a kidney from a deceased human donor can live 12 years, and recipients of an organ from a living donor up to two decades. Slayman managed less than two months, with a handful of medical interventions in between. And Lisa Pisano, who in April 2024 became the second living patient to receive a modified pig kidney, hers from United Therapeutics, passed away three months after her transplant due to heart issues. But Montgomery, who led Pisano’s surgery team, offered a useful reminder.

“Patients on the edge of dying already—patients we’re trying to rescue with a brand-new technology we’re still refining—are just not good indicators of how the science will fare in the long term,” Montgomery said. “We kind of set ourselves up with the most difficult scenario.”

Several days after Slayman’s passing, Williams recalled, he received an invitation to speak at his funeral, held at a Baptist church in Milton, Massachusetts. He wasn’t sure how he would be greeted. His mind traced back to the lingering legacy of the Tuskegee experiments. “When you walk into this kind of congregation, you never know how you’re going to be received,” he told me, “because there may be this suspicion, even if it’s unspoken, that they experimented on this individual—like, This is what they do to Black people.”

At the church, Williams was joined by Slayman’s entire medical team, and he began his remarks by introducing Kawai. Immediately Williams’s fears about his reception vanished. “Before I finish speaking his full name, the

entire congregation gets up and gives us a standing ovation. It was just unbelievable, the energy.”

Recounting to me what he told the packed church, Williams held back his tears.

“I said, ‘He’ll go down in the pantheon of medical history,’” he told me. “I wanted them to understand that he had provided new hope for patients everywhere.”

**I**N THE WAKE OF SLAYMAN and Pisano’s operations, eGenesis and United Therapeutics, along with hospitals around the country, fielded a torrent of inquiries from patients who had spent years on a list for a human donor kidney. It didn’t matter that FDA regulators were still only authorizing expanded access trials. News of the transplants had opened the floodgates. “People were asking, ‘Why not me?’” Curtis recalled. “My health is already declining. Why should I have to wait?”

Curtis, for his part, could only respond with the truth: eGenesis was working as hard as possible to get the technology to more patients. “I’d say, ‘We want the same thing, but we want to do this right,’” he told me. And doing it right would require approval for trials on healthier patients, he went on—patients like Tim Andrews.

A former supermarket manager from Concord, New Hampshire, Andrews, 67, had for two years undergone thrice-weekly dialysis—a process that often took six hours, including travel and prep time, and left him exhausted and weak. When I spoke with him about the difficulty of dialysis, he recalled his appetite disappearing as he dealt with near-constant nausea. He began to stare at the likely reality of never receiving a human organ and of repeating this emotionally draining routine for the rest of his life. As had been the case for Slayman, it was a daunting thing to try to accept.

But last August, Andrews was offered the



**Tim Andrews**  
*Transplant patient*

Andrews, 67, rests at home in Concord, New Hampshire, with his wife, Karen, and dog Cupcake in March, just weeks after receiving an eGenesis pig kidney. The company has partnered with Mass General to perform a limited number of surgeries on healthier patients like Andrews in hopes of eventually offering the option to the wider public.

TONY LUONG

opportunity to undergo xenotransplant surgery at Mass General as part of a new three-patient, FDA-approved trial launched by eGenesis. If he agreed, he'd have the chance to start over. To have, as he put it, "a second chance." His family was leery; his sister, a nurse, warned him about the risks. But he was adamant.

"This is not how I want to go out—I want to do something," Andrews recalls saying. "And I knew that I might die right off. And I said to my wife and to the Mass General team, 'If I die and you learn something, so be it. And if I don't and I get to give people hope—that's what I really wanted.'"



In January, Andrews underwent his transplant, with Kawai leading the surgery team once more. Andrews walked out of the hospital, beaming, wife Karen at his side. Nothing was certain, he knew. Still, he had what he'd hoped: a new lease on life. "Every day," he said, "is a new day."

When we spoke in March, Andrews's recovery was progressing as planned. He goes to Planet Fitness twice a week, regularly takes his nine-year-old German shorthaired pointer on walks, and helps his wife around the house by vacuuming. If all continues to go well, he said, next year the couple will board a plane and visit her relatives in northern Italy.

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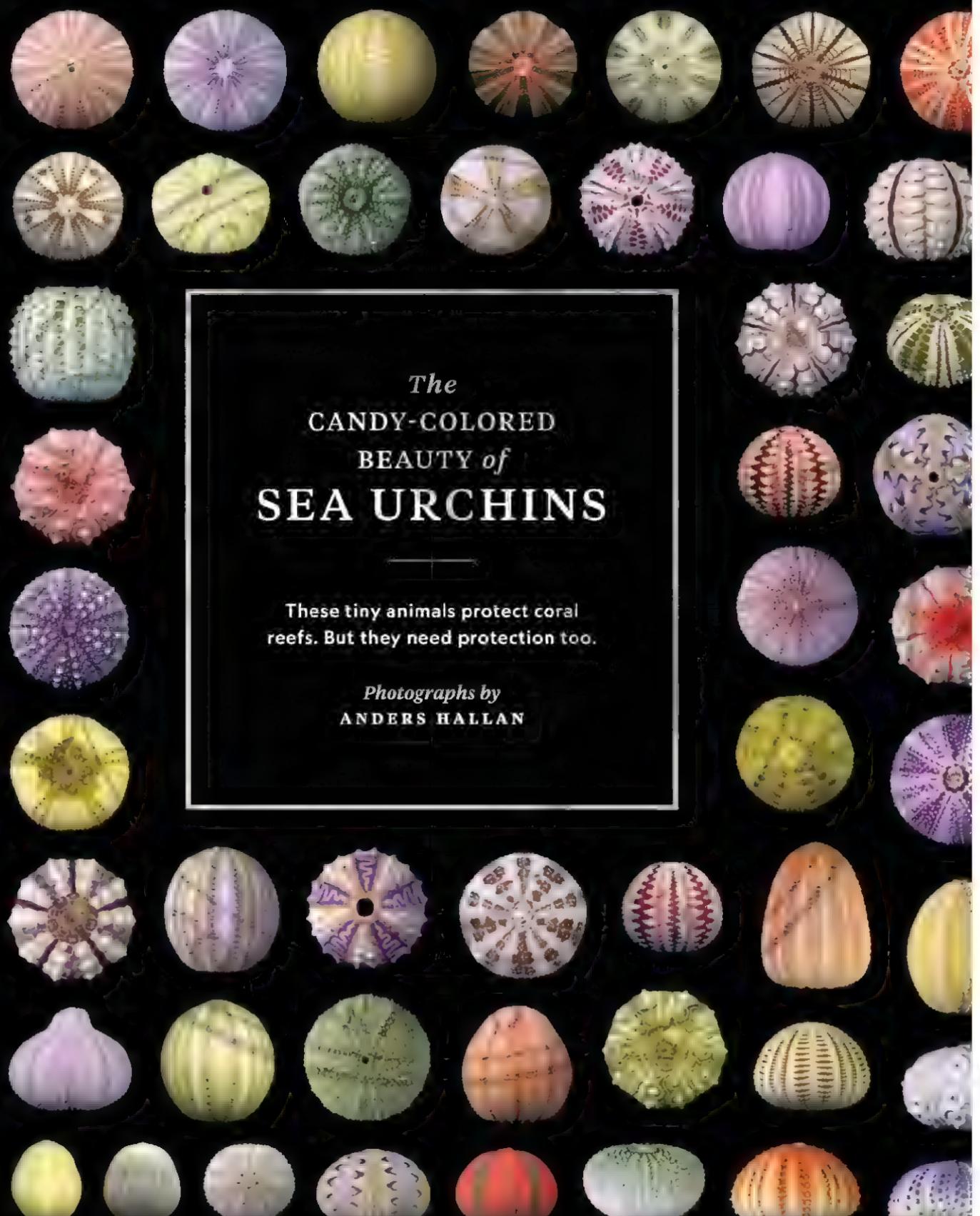
**Tim Andrews**

With his energy returning, Andrews is also trying to serve as inspiration for the tens of thousands of people affected by the organ donation crisis. Every Wednesday night, he meets online with a support group for transplant patients. They encourage one another on their journeys, and, of course, they ask about his porcine kidney. "I want to give that hope to everybody else that's on dialysis or is struggling with kidney disease," he said.

This—an escape from dialysis, a whole-body reinvigoration—is the future. For Andrews, but potentially for dozens of people in the coming years, should the clinical trials expand to a field of 50 patients as planned. And both Andrews and Curtis recognize none of it would be possible without Slayman and Pisano, who proved that the potential of genetically modified kidneys was more than hypothetical and a real solution worth pursuing.

"To get here, we owe so much to brave people like Mr. Slayman, and to all scientists on whose shoulders we stand," Curtis told me. "We have been fortunate to enter the field when we have, because we're able to leverage decades of progress and research and integrate it all into making this thing a reality. You kind of have to pinch yourself. But here we are." □

PROOF



*The*  
CANDY-COLORED  
BEAUTY *of*  
SEA URCHINS

These tiny animals protect coral reefs. But they need protection too.

*Photographs by*  
ANDERS HALLAN



→ **BENEATH SEA URCHINS'** exterior spines, rounded skeletons called tests are jewels of color, texture, and symmetry. There are hundreds of urchin species, and they're found in every ocean on Earth, from the intertidal zone to more than four miles below the surface. In 2018, Anders Hallan, a research associate at the Australian Museum in Sydney, began photographing urchin skeletons that had washed up on beaches or been collected by divers and those on fishing or research vessels. He created the composite image at left over the course of a week in 2024 using 76 individual photographs.

The project comes at a perilous moment for these creatures. Since 2022, sea urchins have been plagued by a scuticociliate, a single-celled pathogen that eats away at the animals' soft tissue and makes their spines fall off. A mass die-off that started in the Caribbean that year has since spread east, likely through the Mediterranean, into the Red Sea and Indian Ocean. In some survey locations, researchers found thousands of dead urchins.

The animals' survival is vital to the health of reefs, where they eat algae that can smother coral. It's one of the many reasons Hallan is committed to capturing their beauty: "They are really quite ingeniously evolved." —HICKS WOGAN

This array of sea urchin skeletons reveals a diversity often hidden from view. The specimens in Hallan's images—more than a thousand in total—are held at the Sea Urchin Science Centre and Gallery in Kurrajong, Australia.



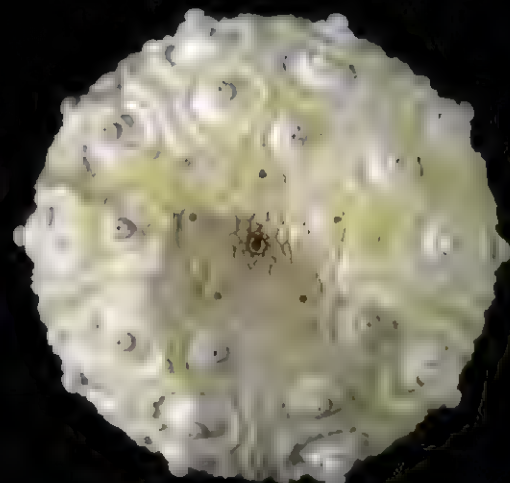
*Stereocidaris granularis rubra*



Hallan often photographs sea urchins from above to exhibit their radial symmetry. On the animal's opposite side, its mouth contains five self-sharpening teeth for chewing foods like algae, kelp, and plankton, and for carving nooks into rocks where it can hide from predators.



*Coelopleurus maculatus*



*Phyllacanthus parvispinus*



*Parechinus angulosus*

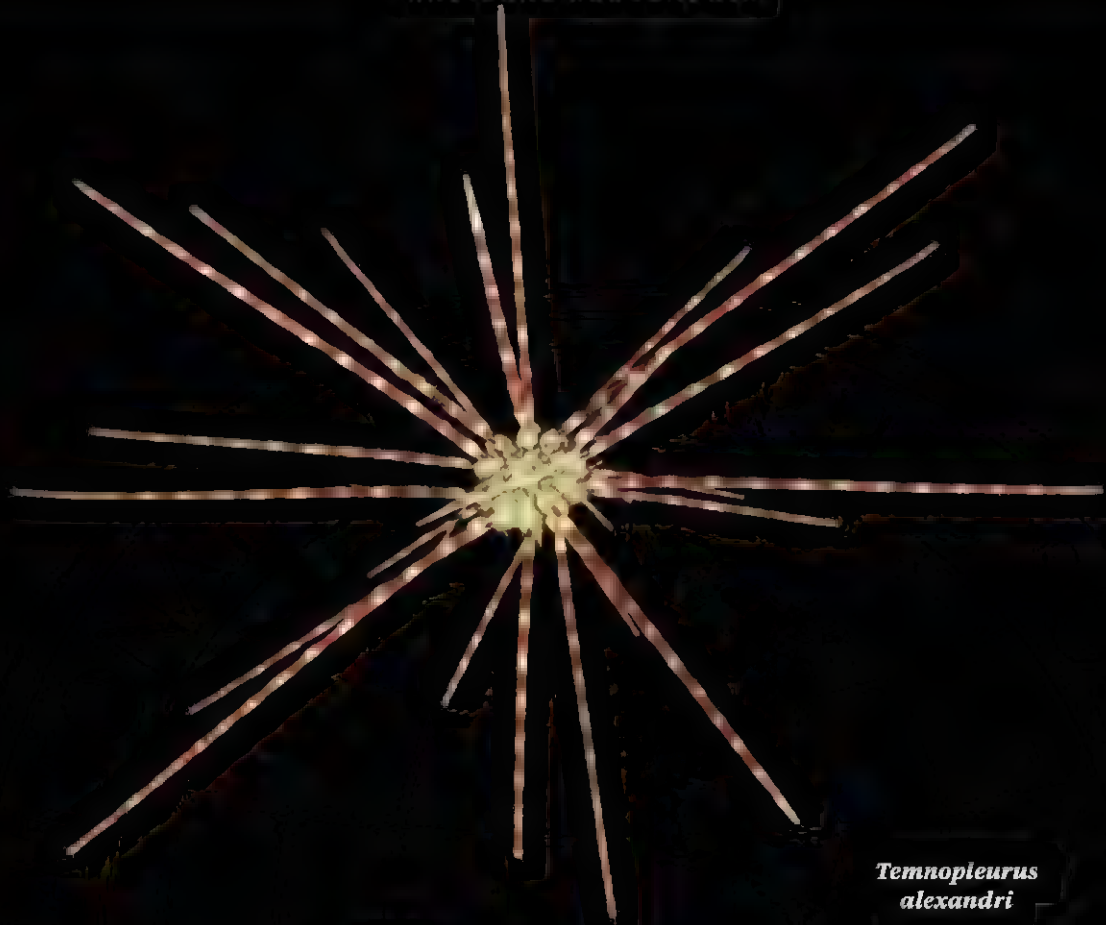
The word "urchin" first appeared in 14th-century English, when it meant "hedgehog." Like their terrestrial namesakes, sea urchins are known for their spines, which are flexible, strong, and serve multiple functions, from defense against predators to locomotion and sensing. Usually the spines detach from the test when an animal dies, but the urchins at right were specially preserved to keep their spines intact.



*Plococidaris  
verticillata*



*Colobocentrotus  
atratus*



*Temnopleurus alexandri*



*Goniocidaris tubaria*



ACROSS THE WORLD,  
HUNDREDS OF MILLIONS  
OF PEOPLE HAVE RELIED  
FOR CENTURIES ON  
DESERT WETLANDS THAT  
ARE NOW VANISHING.  
IN SOUTHERN MOROCCO,  
ONE COMMUNITY IS  
BLENDING ANCIENT  
KNOWLEDGE WITH  
MODERN INNOVATION  
TO PROTECT THE OASIS.

*Photographs by M'hammed Kilito*

*Words by Tristan McConnell*



Five miles from the town of Assa in southern Morocco, these palm trees are all that's left of the once lush Tanoueest Oasis, which has been overrun by sand.





## D R I V I N G

south out of the Atlas Mountains into Morocco's Drâa Valley, travelers find that the landscape becomes increasingly stark until the paved national highway vanishes into the desert at the oasis town of Mhamid el Ghizlane.

Sometimes known as the gateway to the Sahara, Mhamid and its surrounding villages are home to about 6,100 people. For generations, the settlement has straddled the Drâa River, with wispy tamarisk trees lining the road on the north bank of the river and palm plantations spreading out to the south. But today the concrete bridge built to span the water rises over a dry riverbed of sand and gravel. Tourists still come to Mhamid, drawn to camel treks, camping, and sandboarding. They arrive by the busload and make their way to hotels that offer swimming pools and massages.

Halim Sbat, 55, tall and bespectacled, with dark, gray-flecked hair, was born in the town. Like a lot of residents, he remembers a different Mhamid. Greener. Lusher. When he was a kid, he herded livestock beneath the dense shade of thick groves of

At the Tinghir Oasis in central Morocco, crops like barley, alfalfa, and wheat are protected from the desert winds by date palms.

**D** The nonprofit National Geographic Society, committed to illuminating and protecting the wonder of our world, funded Explorer M'hammed Kilito's work on this story.

palm trees and fished in the Drâa, Morocco's longest river, as it wound lazily through town. In the decades since, he has watched the oasis shrivel as the rain has all but stopped and the river has dried up. The thick forests of date palms have withered and thinned, and the fields of fruit and olive trees have produced less and less each year. Most young people have escaped for a better life elsewhere, leaving houses and entire neighborhoods to be swallowed by the encroaching dunes.

"When there is no water, nothing green, the sand becomes very strong, a very fast enemy," says Sbai. "It takes a lot of land." The desert is pressing in from every direction. According to Sbai, the outer edge of the oasis moves inward by more than 300 feet each year. Sometimes Sbai worries that he might be witnessing the end of the oasis altogether and, with it, an ancient ecosystem—and the nomadic culture and traditions it enables—that he holds dear.

For thousands of years people have lived and thrived in oases, developing a complex agricultural system finely calibrated to the harsh desert environment, with its water scarcity and ecological fragility. By some measurements, oases occupy 740,000 square miles worldwide—roughly three times the area of Texas—and in North Africa and Asia sustain an estimated 150 million people. In Morocco, oases are home to one million people. The stresses of contemporary climate change are accelerating with increasing aridity, temperatures, and desertification, as well as destructive floods and wildfires, yet Sbai is an optimist steeped in nomadic culture, and he believes that oases contain the seeds of their own salvation.

**W**HAT IS AN OASIS? An imagined place? A mythical one? An isolated, palm-fringed pool in the desert? A place of safety? Somewhere desperate travelers might find relief, or dismay if the oasis turns out to be a mirage? Ecologically, it is simply an area made fertile by a water source in an otherwise harsh and arid environment. But human ingenuity has transformed oases into complex civilizations.

Ten thousand years ago, northern Africa was hammered by strong monsoon rains and the Sahara was verdant. But the climate gradually shifted, and the grasslands and rivers dried up. In the newly unforgiving desert landscape, water was scarce. Where people found it, they exploited it and created pockets of habitable land that made life not just possible but prosperous, providing homes and livelihoods to many thousands. Radiocarbon-dated barley and wheat grains, as well as millstones used to grind flour, show that oases were already developing in the Drâa Valley during the fifth century.

## The Extraordinary OASIS

For centuries, oases have been important cultural and ecological landmarks in Morocco, despite the fact that they receive fewer than 10 inches of rain each year. They've persisted thanks to clever human engineering that takes advantage of a delicate ecological balance.



### Opportune geography

In the rain shadow of the Atlas Mountains, water flows in intermittent streams and collects in low-lying aquifers.

### Protective palms

Date palm trees, a keystone species, are planted to provide fruit and protect smaller plants from harsh sun, winds, and sands.

### Cooling architecture

Traditional rammed-earth structures with thick, insulating walls protect residents from extreme desert heat.

Hand-pumped well

Solar-powered well

Clay, silt, sand, and gravel

Groundwater

Impermeable bedrock

Intermittent river

Irrigation system

### Mutual caretaking

Agriculture systems require constant maintenance: planting palm trees, removing sand, and collecting water to irrigate crops.

### A fragile equilibrium under threat

Rising temperatures and changing rain patterns due to climate change have exacerbated existing threats, which can have a ripple effect across the delicate oasis ecosystems.

#### Drought

Less rainfall and increased drilling lower water tables and raise fire risks.

#### Bayoud disease

A fungal pathogen has killed significant portions of critical palm groves.

#### Soil salinity

Salt from pumped groundwater accumulates in the soil.

#### Migration

Ecological stress causes community caretakers to flee.

#### Desertification

Vacated land returns to desert; sand pollutes water, fields, and towns.

A potter at the Skoura Oasis in central Morocco, Mohammed El Fakhar spends six hours each Sunday collecting fuel for his kiln.



‘IF WE WANT TO SUSTAIN  
THIS STRUCTURE IN THE  
OASIS, WE HAVE TO  
SUSTAIN THE DATE PALM.’

MOHAMED AIT-EL-MOKHTAR,  
PROFESSOR OF PLANT PHYSIOLOGY



Drought-stressed date palms in Morocco's Tighmert Oasis are especially subject to wildfire. A few weeks before this photo was taken, a blaze struck nearby trees and houses.





Two seasonal workers harvest dates  
in Saudi Arabia's Al Ula Oasis.  
Date palms resist drought and heat,  
but cultivating them is labor-intensive.

As oases grew, so too did Saharan trade. Date palms, the hallmark species of the oasis, are drought and heat resistant, and grow readily in the desert wherever there's water close to the surface. But it takes huge amounts of labor and engineering to successfully cultivate them. These costs were in part met by the salt, gold, and textile traders who plied the caravan routes between Marrakech and Timbuktu. Oases were a place for them to rest and restock before their next expedition. As Sbai puts it, "You can't be a nomad all the time, just moving everywhere. You need to stop, relax."

The essential ingredients of the oasis are date palms and people, and neither flourishes without the other. The thick fronds of the date palm's crown provide a shady canopy beneath which other species can grow, protected from the punishing sun. Scientists have described the date palm as a keystone species for the ingenious three-tiered agricultural ecosystem it anchors. The tree produces valuable dates, and the humid, temperature-controlled microclimate beneath the dense overstory fosters other crops, such as fruit, olive, and henna trees. At ground level, beans, wheat, barley, and alfalfa grow protected from the wind and sand by the palm's tough trunks.

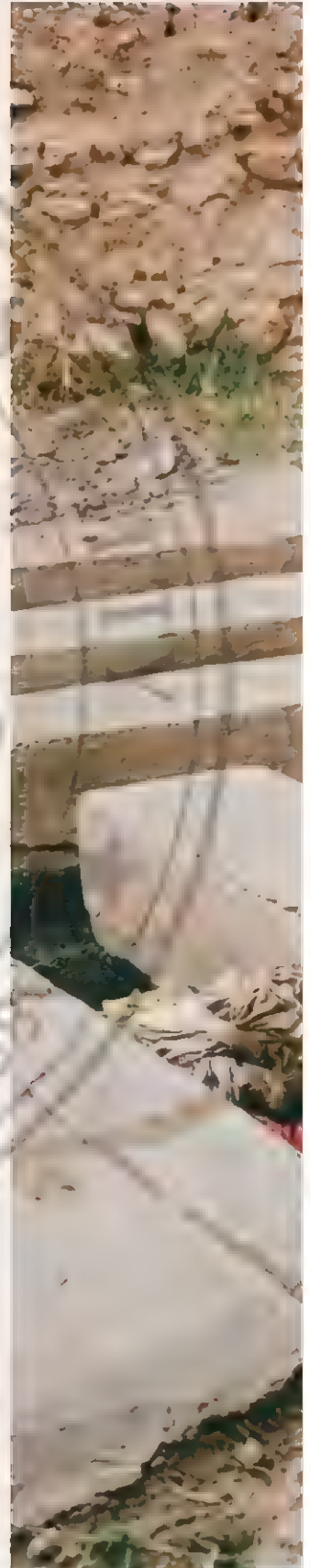
Mohamed Ait-El-Mokhtar, professor of plant physiology and biotechnology at Hassan II University in Casablanca, who has studied the impact of climate change on oasis ecosystems, describes the date palm as "the umbrella" beneath which all else thrives. "If we want to sustain this structure in the oasis, we have to sustain the date palm," he says.

‘THERE IS NO FUTURE  
FOR FARMING HERE  
BECAUSE OF THE WATER.  
IN AGRICULTURE,  
YOU ALWAYS LOSE.’

ABDELKARIM BANNAOUI, FARMER



As the water table drops across much of Morocco, wells like this one at Merzouga Oasis must be dug ever deeper.



Water at the Figuig Oasis in northeastern Morocco is distributed via a network of stone dividers; rights are prescribed by ancestral contracts and are inherited, passed on via marriage, or sold.



Oases worked, in other words, because they stayed in balance. Rainfall in this part of Morocco was always sparse, but still the Drâa was filled with snowmelt and rainwater that flowed more than 11,000 feet down from the peaks of the High Atlas Mountains. Farming communities worked together to dig and maintain geometric networks of irrigation channels to siphon river water into the palm plantations. They used stone, mud bricks, and rammed earth to build warren-like fortified homes and villages—known as *ksars* and *casbahs*—and expanded their agricultural lands into the increasingly irrigated desert.

But climate change has devastated many oases, and it's only expected to get worse. Temperatures in Morocco are projected to rise by as much as nine degrees Fahrenheit by the end of the century, and rainfall to be reduced by 30 to 50 percent. Extreme flooding is on the rise, and government figures show that around 10,000 palm trees burn every year in wildfires.

**N**EAR MHAMID, THE PALMS survive largely because farmers use groundwater extracted with individual solar pumps to irrigate their plots. They are cheap to run and make extracting water easy, but they are a short-term fix. The brackish groundwater increases the salinity of the soil, making growing crops even more difficult; and pulling straight from the aquifer can put it out of reach of even the deepest palm tree roots. "As long as people keep pumping groundwater with solar, they think there's no problem," says Sbai. But "when you use solar, you can very quickly kill the oasis."

Abdelkarim Bannaoui, a 48-year-old with a thick mustache and dressed in a white tunic and turban, has farmed in Mhamid all his life. When he was growing up, there were periods of drought that would decimate crops, he says, "but the palms stayed strong." Now even they wither, and date yields are falling. The palm cover on his acre plot is scant, and the fruit trees are gone. Unable to rely on the river or rain for irrigation, he uses groundwater pumped from his own well at the far end of his land, and every few years he must dig it deeper. In 1996 a 23-foot well was enough; now it reaches to 52 feet.

"It is in God's hands," Bannaoui says, "but as I see it, there is no future for farming here because of the water. In agriculture, you always lose." He expects that eventually his three young sons, all of whom are under 10, will abandon farming and the oasis.

In a destructive feedback loop, migration hastens the oasis's surrender to the desert. The local population has fallen by a fifth in the past 20 years, and as mostly young people leave, it's harder for the aging population that remains to maintain the palm trees and irrigation

channels. "There is nothing to do here because there's no rain, so people emigrate," says 61-year-old farmer Abdelaali Lahbouch, whose three sons have left. "There is nobody around, just us old people."

In his long white djellaba and purple scarf, Lahbouch takes me to see the sand-filled irrigation channels and sand-covered fields nearby. "There's nobody here to help us work," he says, shrugging. Neglected and abandoned plots let the desert in, and a few days of strong wind is all it takes to coat the earth with sand, starting the process of soil degradation.

As we walk around Bounou, one of Mhamid's satellite villages, Sbai tells me that of the 200 families that used to live here, only five remain. The rest, he says, have seen their homes taken by the desert. There are no longer enough residents to clear the sand-clogged alleys and passages, nor to maintain and repair the rammed-earth walls of the ksar, which are crumbling and collapsing like a sandcastle in a rising tide. One of the few still living here is 68-year-old Belaaïd Lagnaoui, a thick-set farmer who long ago ceded the ground floor of his mud-walled house to the desert. From his perch upstairs, he uses the flashlight on his phone to peer at the sand-filled hall below.

**I F THERE IS ANY CHANCE** of rescuing Mhamid and charting a path toward saving other oases across the world, it might come from a small, two-acre plot on the edge of town, where Sbai has constructed a laboratory of pilot projects aimed at holding back the desert and holding on to water.

Acacia and tamarisk trees sprout from shallow circular planters called Waterboxxes that were designed by a Dutch horticulturalist named Pieter Hoff. These planters reduce the amount of water young saplings need and act as a barrier against the desert. For years, Sbai has worked with a Dutch foundation called Sahara Roots planting hundreds of trees around Mhamid to strengthen what he calls "the natural system to stop the sand." He has also introduced pipes for drip-fed irrigation, which snake across vegetable beds and use far less water than the traditional method of flood irrigation that ceased to make sense when the river stopped flowing.

These solutions, though modest in scope, are all aimed at restoring and recalibrating the balance between the people of the oasis and the changing landscape in which they live. Take the solar pumps. Climate change has made them necessary, but when they're privately owned, as most currently are, people take what they want, regardless of the needs of others. Sbai has been pushing local farmers and government agencies to reconsider how the pumps are used. "In nomadic culture," he says, "you need to share everything." Thanks in part to Sbai's





Like all open-air canals in the desert, this irrigation canal leading to Tighmert Oasis requires constant attention and maintenance from locals like Fal Bardid to keep it from filling with sand.

lobbying, Morocco's National Agency for the Development of Oasis Zones and Argan Trees is working to install community solar pumps and wells to replace private ones in Mhamid and elsewhere so that water can once again be managed communally and shared equitably.

Of course, none of that will matter if the entire population of Mhamid leaves for better opportunities elsewhere. So in 2016, Sbai co-founded the Joudour Sahara music school with Thomas Duncan of the Playing for Change Foundation, a California nonprofit that uses music to bring communities together. "We asked, What can you offer young people to make them stay?" says Duncan. Their answer is to celebrate, share, and preserve knowledge of the cultural traditions of the desert and the oasis. Children attend weekly music classes in the traditional Ahidous, Gnawa, Rokba, Akalal, and Chamfa styles. The school has since given rise to the Zamane Festival, which features hundreds of musical artists from across the Sahara and attracts thousands of visitors.

The school's new home, the Joudour Sahara cultural center, was completed last year and consists of two modern rammed-earth buildings, designed by Moroccan architect Aziza Chaouni. One is a sunken amphitheater for musical performances, the other a classroom with a subterranean cistern. The two structures are connected by underground water pipes. Rainwater is collected and stored in the reservoir. "Real resilience is saving every drop of rainwater," says Sbai. A *riad*-style building for visiting musicians is under construction

‘WHAT CAN YOU OFFER  
YOUNG PEOPLE TO  
MAKE THEM STAY?’

THOMAS DUNCAN, CO-FOUNDER  
OF JOUDOUR SAHARA MUSIC SCHOOL




Mohammed Zriouili's family is one of just four left in Ait Mohammed, a village in the Tighmert Oasis that was once home to around 100 families. Most moved to big cities in the north.

As oasis towns hollow out, buildings fall into disrepair;  
eventually they'll be reclaimed by the desert.







Mhamid el Ghizlane, in southern Morocco, is sometimes known as the gateway to the Sahara. It straddles the Drâa River, which rarely contains water anymore.

nearby. "The idea was to revive traditional materials that completely make sense in the area," says Chaouni, "to build pride in traditional architecture, not to just copy the past but be innovative."

Sbai often talks about the importance of nomadic culture, the need to live within the constraints of nature and the desert's tough environment, to share resources as a community, to not waste anything. He says these old ways are key to the restoration and survival of the oasis in the face of climate change.

Sbai started as a tour operator before expanding into environmental and cultural activism. He still believes in the value of tourism to the oasis economy, but, he wonders, what kind of tourism? The kind that builds with concrete, fills swimming pools with precious water, and tears up the dunes for gasoline-fueled kicks? Or something slower and simpler, that treads more lightly on the land, exists in harmony with the landscape, and draws on the rich culture and history of the oasis?

One cold, clear evening, he reclines against a thick pouf on a handwoven carpet laid out by a fire. One of his guests is a Tuareg desert blues guitarist visiting the music school from Mauritania, who carefully serves tea poured from a small painted teapot heated in the fire's embers. A waxing moon shines bright above, and a thick stand of date palms is silhouetted against the indigo sky. "We have the stars and a fire," Sbai says. "We are the luckiest people on Earth." The oasis is fragile, its future uncertain, but it is where Sbai comes from and where he belongs, and he is determined to save it. □

## LOOKING *More* *Closely for* LEMURS

Researchers have long worried about the dwindling numbers of ring-tailed lemurs. Now they're getting some good news.

Photograph by JOEL SARTORE

→ **RING-TAILED LEMURS** are some of the most beloved creatures in the world, thanks in no small part to the *Madagascar* movie trilogy, which features comedian Sacha Baron Cohen as king of the lemurs. Despite their popularity, the charismatic, cat-size primates are incredibly difficult to find in real life—they live only in remote and hard-to-reach areas of south and southwestern Madagascar. “Roads are often impassable, if they exist at all,” says Andrea Baden, a primatologist at Hunter College in New York City. For years, population numbers were determined by extrapolating from limited surveys, leading some scientists to believe the primates were in steep decline. Then, in 2018 and 2019, Baden and her team carried out an extensive population assessment and were surprised to find the primates were still eking out an existence in 65 of the 83 sites the researchers visited, including three where the animals were thought to have disappeared. “We basically doubled the estimated population size just by expanding our efforts,” Baden says of their findings, which were published in 2023 in the journal *Oryx*. The species is still under threat from habitat loss, non-native predators like dogs and cats, and the illegal pet trade. But the team’s findings have helped get the lemurs off the International Primatological Society’s list of the World’s 25 Most Endangered Primates. —JASON BITTEL



**PHOTOARK**  
JOEL SARTORE

The National Geographic Society funds Explorer Joel Sartore's Photo Ark project, which aims to document every species living in the world's zoos, aquariums, and wildlife sanctuaries.



AFRICA

MADAGASCAR

AFRICA

Mozambique Channel

COMOROS

Cap d'Ambre

MADAGASCAR

Antananarivo

Possibly extinct

200 mi  
200 km

Ring-tailed  
Lemur range  
Cap Ste.-Marie

INDIAN  
OCEAN

SCIENTIFIC  
NAME

*Lemur catta*

TYPE

Mammal

DIET

Omnivore

AVERAGE  
LIFESPAN

Up to 20 years  
in the wild;  
mid-30s in  
managed care

AVERAGE  
WEIGHT

5 to 7.5 pounds



MAP: MATTHEW W. CHWASTYK, NGM STAFF. SOURCE: IUCN RED LIST  
PHOTOGRAPHED AT LINCOLN CHILDREN'S ZOO, NEBRASKA

*Are We  
Sure*  
**PLUTO**  
*Isn't a*  
**PLANET?**

Nearly 20 years since it was  
downgraded to a dwarf planet, Pluto's  
bona fides still spark debate.

*Interview by*  
ERIC ALT

*Illustration by*  
JAKOV JAKOVljević

➔ **AFTER ITS DISCOVERY IN 1930**, Pluto was declared the ninth planet in our solar system and quickly garnered attention not typically afforded to its galactic peers. This was thanks in part to the power of celebrity. The small, multicolored, icy rock has long been associated with Mickey Mouse's pet dog (which was originally named Rover but most likely renamed after the planet in 1931).

Then, in 2005, Mike Brown, a professor of astronomy at Caltech, crashed the party upon discovering Eris, similar in size to Pluto and also in the Kuiper belt, calling into question Pluto's classification. As a result, in 2006, the International Astronomical Union (IAU) voted to adopt new

requirements for planetary status—kicking Pluto out of the club and into the newly defined category of dwarf planet. (Brown expanded on his reasoning in his aptly titled memoir: *How I Killed Pluto and Why It Had It Coming*.) In the years since, the worlds of science and pop culture have hotly debated Pluto's fate. Among Brown's good-natured adversaries is Philip Metzger, a retired planetary physicist at NASA's Kennedy Space Center, current associate scientist at the University of Central Florida, and avowed Pluto-is-a-planet believer.

To celebrate the 95th anniversary of Pluto's discovery, we sat down with Brown and Metzger to get some clarity. Are Brown



and his cohort correct in reducing Pluto's significance and instead focusing on new discoveries like the still unconfirmed Planet Nine? Or do Metzger and others have a solid argument for the triumphant return of everyone's favorite little planet?

**Mike, how did you arrive at your conclusion that Pluto isn't a planet? And Philip, how did you wind up on the other side of the fence?**

**MIKE BROWN:** Since I've been at Caltech, one of my main areas of research has been the objects in the outer part of the solar system and Kuiper belt, objects like Pluto. And one of the largest projects that I did back in the early 2000s was the first really wide-scale search for other objects as large as Pluto, other dwarf planets... before we called them dwarf planets, which, by the way, is a stupid term.

**How so?**

**MB:** Because it's unnecessarily confusing. Before the IAU made up that term, we used the word "planetoid" to describe these things that are small but round, and it's a much better word because it's not as confusing. The only reason that Pluto was called a dwarf planet [after its planet status was revoked] is because that was snuck in there by the pro-Pluto people in hopes that they could then get a vote that dwarf planets are planets. The vote was then overwhelmingly rejected, but we're left with that stupid phrase. I blame the Pluto people for that.

**PHILIP METZGER:** We would say that there are a lot of dwarf planets and that these dwarf planets are actual planets in the Kuiper belt. But the thing is, we're not really arguing for Pluto to be reinstated, because

we think that the vote to downgrade it was irrelevant. The IAU didn't have a right to do that vote. They violated their own bylaws when they did it... Our claim is that it never stopped being a planet because taxonomy is part of science, and the taxonomy that matters is the one that the scientists are using and finding useful. Whereas the public's astrological-based taxonomy is not useful for science. It doesn't align with any theories, and that's unfortunately the one that the IAU adopted.

**Well, let's start there. What are the criteria for planet status?**

**PM:** In 2006 the IAU decided, number one, that [a planet] must orbit a star directly. Based on that, the moon would not be a planet. (It's what we call a secondary planet, whereas the Earth is a primary planet.) The second thing they said is that [a planet] has to be large enough to pull itself into a round shape by its own gravity, what we call gravitational rounding. And then the third condition was—and this is the one designed to eliminate bodies like Pluto—it has to gravitationally dominate its orbit in order to clear the neighborhood of its own orbit from other bodies. They didn't define what they meant by that. They just figured people would make it more concrete later. You could argue the Earth is not a planet because the Earth doesn't clear out its own neighborhood. What they really meant was [a planet] has to be gravitationally dominant according to some unknown metric that they hadn't created yet.

**MB:** In the early 2000s, digital cameras started to get much, much better, and we could finally take pictures of the whole sky at once. We used that to discover these biggest, brightest, dwarfiest planets that are out there, including the one that really forced a discussion about Pluto. We

discovered Eris, which is more massive than Pluto. And so suddenly, something was going to have to give. You were either going to have to add new planets or subtract things that are no longer planets. If Pluto were discovered today, nobody would say it was a planet.

**Are we too hung up on the number nine? Have we just all grown up with nine planets, and the thought of either eight or infinite numbers of planets makes us uneasy?**

**MB:** No, there is no magic number. It's not that Pluto had to be subtracted; it's that astronomers were forced to acknowledge [the] reality that it didn't fit with what we know about planets now. The pro-Pluto side tried to change the definition of a planet to be something it's not because they were so desperate to keep Pluto a planet, but their definition would add 200 more planets to our solar system. The pro-Pluto faction, by the way, is dominated by people who were involved in the NASA mission to Pluto. When they launched, Pluto was a planet. By the time they got there, it wasn't.

**PM:** It's cultural; it's not scientific. What else in nature is like that? I mean, we don't say there have to be only nine mountains, nine rivers, nine types of beetles.

**In elementary school we were told that there are nine planets—that's it. Should it be taught as more of an evolving concept?**

**PM:** Yeah. Unfortunately, when we're taught that there are only eight planets and these planets reign in their orbits; we're hearkening back to the old geocentric concept. [This outdated idea is] just simple, orderly, monocentric, and these planets are like gods. They reign in their orbit. We're arguing they need to teach that it's

a dynamic cosmos. Things change, things evolve. Planets can change their orbit.

**Scientists have hypothesized that there might be a replacement for Pluto—so-called Planet Nine. But that's not just because they want a replacement for Pluto, right?**

**MB:** Right now, [the existence of Planet Nine is] a very good hypothesis to explain a lot of things we're seeing out there that we have no other explanation for. [But] until the day that we point a telescope at it and see it and say, "Aha, there it is," it is just the best hypothesis to explain these phenomena.

**In the end, why do you think people have such an attachment to Pluto—and a resistance to Planet Nine or other possible "replacements"?**

**PM:** All I can say is, when the New Horizons spacecraft flew by Pluto, it was amazing. I was at Johns Hopkins University where they had the control center. When they put up the pictures for the first time, it was just so breathtaking... and geologically diverse. I mean, there are mountains as tall as the Rocky Mountains, and there are glaciers flowing, and there's a layered atmosphere, and there's probably an underground ocean, and there's organic material. The building blocks of life all over the surface of the planet. Not only is Pluto a planet, but it's also more of another Earth than any other. It's the most planet-like planet.

**MB:** I have an attachment to Pluto. [When I was] growing up, it was this weird, mysterious thing at the edge of the solar system. Who would not think it's kind of weird and small and cute? And now we've seen pictures of it. It is kind of cool looking. It's a cool place. □

# WHAT WE CAN LEARN

Words by  
**BEN GOLDFARB**

Photographs by  
**RONAN DONOVAN  
& KHOLOOD EID**



OF

# BEAVERS



Beavers on Montana's Crazy D Ranch harvest a large cottonwood tree to construct dams and lodges.

RONAN DONOVAN

# FROM THE GENIUS

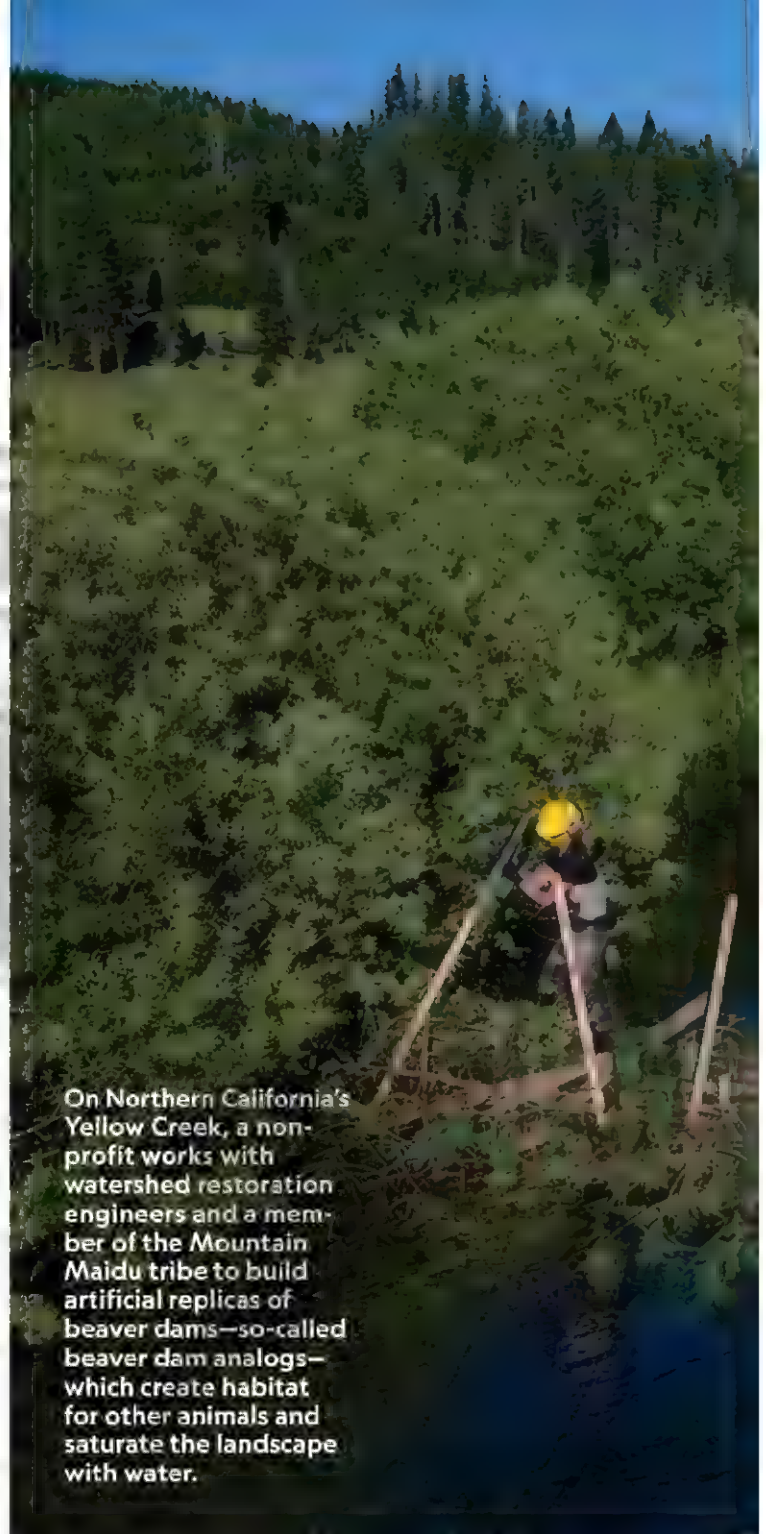
FIRST, THEY  
WERE PELTS,  
THEN PESTS. BUT  
NOW THEY ARE  
EMERGING  
AS SOMETHING  
ELSE: **CLIMATE  
HEROES.**

**T**HE EAST TROUBLESOME fire erupted on October 21, 2020, whipped by strong winds and fueled by drought-parched forests. The fire roared through northern Colorado's spruce and fir woods; it leaped roads and rivers and the Continental Divide, scaling mountain passes above tree line. It incinerated historic buildings in Rocky Mountain National Park and homes in Grand County, killing two people. Ultimately, it torched nearly 200,000 acres, making it the second largest fire in Colorado's history.

In the end, just about the only thing the East Troublesome didn't consume was beaver ponds.

This was not entirely surprising. Beavers, of course, build dams that store water—and water, as you may know, doesn't burn. But the benefit the semiaquatic rodents provide goes further than that. In a study published weeks before the East Troublesome blew up, Emily Fairfax, an ecohydrologist now at the University of Minnesota, found that beaver ponds and canals irrigate the landscape so thoroughly that they turn crisp, flammable plants into lush, fireproof ones, forming green refuges in which wildlife and livestock can retreat. In a nod to another firefighting icon, Fairfax and her co-author titled their paper "Smokey the Beaver."

Fairfax studied five fires between 2000 and 2018 to reach her conclusions. But the East Troublesome was far bigger than most



On Northern California's Yellow Creek, a non-profit works with watershed restoration engineers and a member of the Mountain Maidu tribe to build artificial replicas of beaver dams—so-called beaver dam analogs—which create habitat for other animals and saturate the landscape with water.

of those blazes—and a harbinger of the kind of conflagration we're seeing more and more. Although fire has long been a natural force of regeneration on North American landscapes, the so-called megafires that plague the ever drier West are a different matter, stoked by climate change into explosive infernos that burn so big and hot that ecosystems don't always readily recover. Fairfax doubted

KHOLOD F.D



whether beavers could still fireproof large tracts of the landscape under those conditions. But when she visited the charred forests left behind by the East Troublesome and one other megafire, she discovered that the oases beavers created with their ponds had endured. “There are entire rivers that are basically unaffected by the fire, because it’s just beaver dams the whole way,” she said.

“Everything is full of life: The reeds are growing; the pine needles are still on the trees.” The ponds aren’t merely helpful before a fire—they can also protect ecosystems from the effects that come right after a blaze, capturing the ash and debris that run off hillslopes and shielding downstream fish and drinking water. In a 2024 paper describing their findings, Fairfax and her collaborators





A beaver swims back to its lodge underneath the frozen surface of a creek in Bozeman, Montana. Beavers don't hibernate, so they spend the entire fall stockpiling wood underwater to feed on through the winter.

RONAN DONOVAN

The lush ribbon of the Baugh Creek watershed, in central Idaho, has been restored in the aftermath of the 2018 Sharps fire, which burned 65,000 acres. Beaver dam analogs built by land managers capture the ash and debris that run off hillsides after fires.



concluded that beavers “can be part of a comprehensive fire-mitigation strategy.”

Once hunted to near extinction for their pelts and later villainized as a nuisance, beavers have rebounded. There are now 10 to 15 million swimming and waddling across most of North America, and they’re ready for their third act, cast in an improbable role: ecological saviors to a climate change-ravaged world. And fire mitigation is just the start. By building dams that slow streamflow, they create reservoirs that help combat drought; by sculpting wetlands, they furnish habitat for other animals.

Nowhere is their return more necessary than in the climate-stressed American West, where beaver restoration is unfolding, to some extent, in every state. But beavers,

tireless meddlers with a penchant for running afoul of human infrastructure, aren’t yet universally welcome.

**T**HE SAN PEDRO RIVER snakes across Arizona’s border with Mexico through the sunblasted Sonoran Desert. Though the arid land seems better suited for rattlesnakes than for semiaquatic rodents, frontiersmen once knew the San Pedro as the Beaver River—before 19th-century trappers stripped it clean. “Anywhere there were perennial waters, there were probably beavers,” Lisa Shipek, the director of a nonprofit called the Watershed Management Group, told me one fall day along the San Pedro’s cobble-strewn banks.

RONAN DONOVAN



In 1999, in hopes of enhancing the area's wildlife habitat, the federal Bureau of Land Management restocked the San Pedro with 16 beavers, whose offspring dispersed throughout the river, including into Mexico. Since 2020, Shipek, along with Mexican biologists and legions of volunteers, has been scouring the river to estimate their population. I joined her team for a day of surveying the San Pedro's shady cottonwood galleries for beavers' chew marks, tracks, and lodges. Along the trunk of one downed cottonwood, beavers had chiseled away the bark to expose cream-colored heartwood and whittled limbs to blunt points. Pale chips littered the bank. "They were probably here within the last few weeks," Shipek half-whispered.

It's easy to empathize with beavers. Like

many of us, they live in nuclear families: A typical colony consists of a breeding pair and their offspring, which stick around until the age of two. On land, beavers are clumsy morsels for cougars, wolves, and bears, but they're balletic swimmers, endowed with transparent eyelids and webbed hind feet. Their keratin-scaled tails serve as fat-storage units and rudders; their iron-reinforced teeth scrape away the inner bark that provides the bulk of their herbivorous diet. By building dams and filling ponds around their woody lodges, beavers expand and defend their aquatic domains, like feudal lords with moats around castles.

Like humans, too, beavers are survivors. Just as *Homo sapiens* are the last in a long line of hominins, the world's two beaver species—*Castor canadensis*, the North American beaver, and *Castor fiber*, its Eurasian cousin—are vestiges of a diverse family. Their now extinct relatives include *Castoroides ohioensis*, which grew nearly as large as black bears. Although it's tempting to imagine *Castoroides* constructing Hoover Dam-size walls, the species likely didn't dam at all and died out during drier conditions. Modern beavers may have endured precisely because they could modify nature on a warming planet.

As beavers proliferated, they shaped the land. At one time, as many as 400 million of them roamed North America and constructed up to 250 million ponds. Those beaver-built bodies of water bolstered amphibian and salmon populations, supported mammals from muskrat to moose, and aided songbirds, which perch in coppiced willows and eat aquatic insects. Indigenous peoples have long understood beavers' importance: The Blackfeet environmental historian Rosalyn LaPier notes that the tribe believes beavers are divine animals that can talk with humans and venerates them for the ecological oases they create. But colonists didn't share that respect. In the 1500s, beaver pelts came into vogue in Europe. They were used for elegant hats, which milliners felted from beavers'

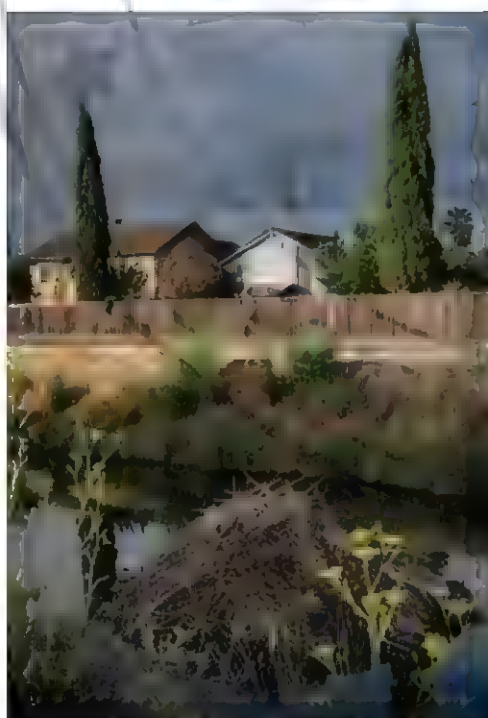
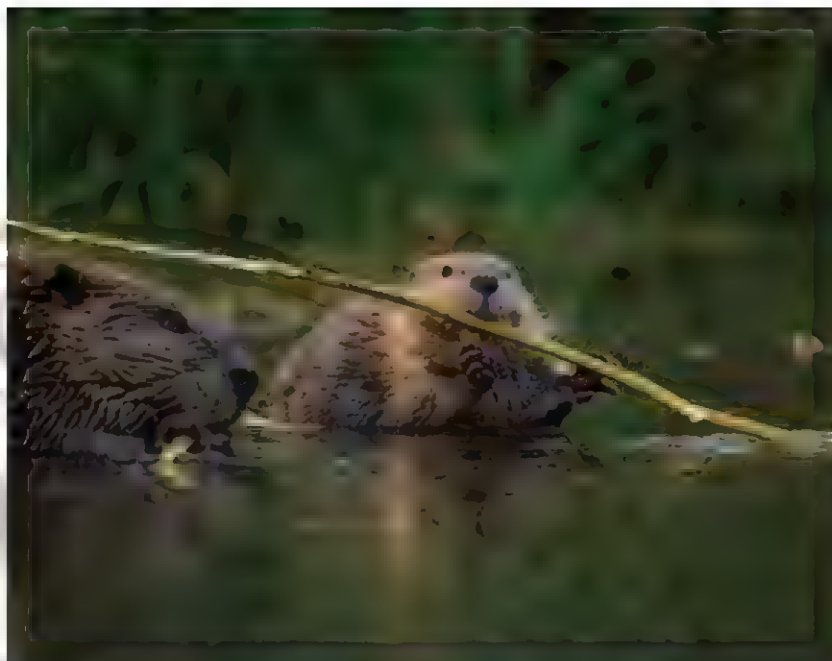


*Opposite page:* Heidi Perryman is president of Worth A Dam, a nonprofit in Martinez, California, that works to protect local beavers.

*This page, top right:* Beavers feed on the bark of small branches in the East Gallatin River in Bozeman.

*Bottom right:* The New Mexico Trappers Association's Tom Fisher, often called to remove problem beavers from people's land, checks beaver traps in Rio Arriba County.

*Bottom left:* A beaver lodge is part of a neighborhood in Fairfield, California.



## BENEFITS OF BEAVERS

These engineers create their watery kingdoms to evade predators and access food. But their habitat modifications also provide surprising advantages for entire ecosystems.

Graphic and map by  
**FERNANDO G. BAPTISTA,  
SOREN WALLJASPER,  
and AMANDA HOBBS**

### ARRIVING

Young beavers set up on the river at around two years old. When they find suitable habitat, they first build a bank den and dam.



### EXPANDING

As the water slows, sediments collect and the streambed widens. Beavers build a lodge, store food, and make new dams.



Beavers often live in an anchor one upper incisor into the tree, then gnaw the wood with a bottom incisor.

When they're hungry, beavers use their tails for balance, for storage, and as a communication.

SOURCES: EMILY FAIRFAX, UNIVERSITY OF MINNESOTA; JOE WHEATON, UTAH STATE UNIVERSITY.

## 5

5

10





Velcro-like underfur. To meet the demand, fur trappers and traders purged beavers from practically every waterway on the continent. As the animal vanished, wetlands dried up and streams eroded, a cataclysm akin to an aquatic dust bowl.

Yet beavers weren't finished. In the early 1900s, many states enacted trapping restrictions and reintroduced beavers from places like Canada and Yellowstone National Park. Some land managers got creative: In 1948 the Idaho Department of Fish & Game packed beavers into crates and dropped them by parachute into the wilderness. Two years later, the *Journal of Wildlife Management* reported that "beavers had built dams, constructed houses, stored up food, and were well on their way to producing colonies."

As beavers have slowly returned to the West over the past several decades, their helpfulness has grown more appreciated—just as our climate woes have multiplied. Their ponds store and gradually release rainfall and snowmelt, compensating for dwindling snowpack. By allowing water to seep into floodplains, they also hydrate soils and recharge aquifers. One 2022 study that tracked relocated beavers in Washington State found that the average pond stored more than a quarter million gallons of surface water and over 600,000 gallons of groundwater. "Beavers are slowing the flow, holding on to water longer, and mimicking the function of the depleted snowpack," said Joe Wheaton, a geomorphologist at Utah State University. "If that isn't serving a societal need, I don't know what is."

In the San Pedro River, Shipek estimates that up to 21 beavers now live on the Arizona side of the border and perhaps 17 more in Mexico—though the populations are divided by a metal floodgate that is part of the border wall. During our survey, we saw ample chew and a few lodges but no dams. Still, Shipek hopes that beavers could someday restore the bountiful wetlands that long ago prevailed in many desert watercourses—and help the

Southwest

"I can't have too waded the river. Beaver marshes seem so local species in this area."

**A**

down on the Oregon side, generally. USDA's V with pro one beaver where they're re

On a b slogging Oregon, of Portland stems has sucked a buzzed i across the city's water transluce "Those 1 Pacific tr

This po here. In elaborate as the C Quality I als, nitr ran off st and Will beavers humans' the dam beavers c

st address its water woes.

only imagine how different it would  
ked," Shipek said wistfully as we  
rough the shin-deep flow of the for-  
er River, envisioning the ponds and  
that once shimmered here. "It just  
important to bring back this criti-  
es. It's the evolution of restoration  
ea."

**IF BEAVERS REOCCUPY** floodplains  
and stream corridors, they risk  
becoming victims of their own  
success. The rodents gnaw  
chards, flood roads, and block irri-  
gation canals, mischief to which landowners  
respond by calling trappers. The  
Wildlife Services program that deals  
problematic animals kills an average of  
one every 22 minutes. But in the places  
communities are learning to coexist,  
reaping surprising benefits.

One blue May morning, I found myself  
wading through a wetland in Gresham,  
a city of 112,000 a dozen miles east  
of Portland. A beaver-built weave of willow  
branches had formed a pond whose mucky floor  
was up to my boots. Red-winged blackbirds  
were in the bushes; wood ducks glided  
on the glassy surface. Katie Holzer, the  
wildlife scientist, scooped up some  
jelly peppered with black specks.  
The little dots are the embryos of the  
American tree frog," she said.

A pocket of biodiversity wasn't always  
there. In 2008 Gresham had excavated an  
underground maze of berms and canals, known  
as the Columbia Slough Regional Water  
Treatment Facility, to capture the heavy met-  
als, and pesticides that habitually  
leaked into the nearby Columbia  
and Yamette Rivers. To the city's dismay,  
the beavers dammed the ditches, sabotaging  
the best-laid plans. Workers destroyed  
the dams and trapped the beavers, but the  
beavers came back.

The animals, Holzer finally figured, were  
there to stay—so why not study them? When  
she analyzed the water trickling past their  
dams, she discovered something extraordi-  
nary: Beaver ponds were cleaning Gresham's  
stormwater better than the water-quality  
facility had without them. Mercury, copper,  
lead, and zinc settled out in ponds and were  
trapped within the sediment, and woody  
lattices of dams further strained out con-  
taminants. Bird diversity increased, and sal-  
amanders hid in the dams' cool crevices. Beavers,  
Holzer said, "are a perfect  
self-maintaining system.  
After every storm, they  
come out and patch things  
up for free."

The city's relationship  
with beavers was still  
fraught: The resourceful  
animals were inundating access roads and  
clogging the wastewater facility's pipes.  
Instead of killing the troublemakers, city  
officials hired Jakob Shockey, a mop-topped  
biologist whose truck sported B3AV3R vanity  
plates, to mediate. I found Shockey waist-  
deep in a pond behind a culvert packed  
with sticks and mud. "Beavers are plugging  
this up so often that they have to clean it out  
once a week," Shockey said, wiping his brow.  
Shockey had been tasked with crafting a per-  
manent solution, including fences to keep  
beavers from blocking culverts and pipes to  
lower road-flooding ponds. A study showed  
that such nonlethal interventions work up to  
96 percent of the time, and they save money  
to boot.

"The best thing we can do for beavers,"  
said Shockey, "is to partner with them in the  
places they've chosen to live."

Like Holzer and Shockey, researchers and  
policymakers around the country are trying  
to let the animals thrive. In Montana, a new  
Beaver Conflict Resolution Program helps  
landowners solve their beaver problems  
without resorting to traps. In Maryland,

ecologists are counting on beaver ponds  
to filter out nitrates polluting Chesapeake  
Bay. Some of the swiftest progress is happen-  
ing in California, which in 2023 launched a  
statewide beaver program that set aside  
\$1.4 million to implement beaver restoration  
initiatives. That same year, California's  
Department of Fish and Wildlife released  
seven beavers onto the ancestral lands of  
the Mountain Maidu, the state's first official  
relocation in almost 75 years.

**'The best thing we can do for  
beavers is to partner with them in  
the places they've chosen to live.'**

**—JAKOB SHOCKEY, BIOLOGIST**

Other tribes are also welcoming beavers  
home. In California's Klamath River water-  
shed, the Yurok Tribe's fisheries department  
has constructed beaver dam analogs, human-  
built dams designed to imitate beaver activity,  
encourage the rodents to return, and create  
sheltering ponds for juvenile salmon. Some  
young salmon have since gone to sea and  
come back to spawn, a strong suggestion that  
the tribe's beaver-based approach is working.  
Higher up the Klamath, the removal of four  
massive hydroelectric dams has recently  
helped fish reclaim their spawning grounds.  
Yet nearer the river's mouth, the beaver-  
inspired dams—small and permeable rather  
than colossal and concrete—have also pro-  
duced substantial gains.

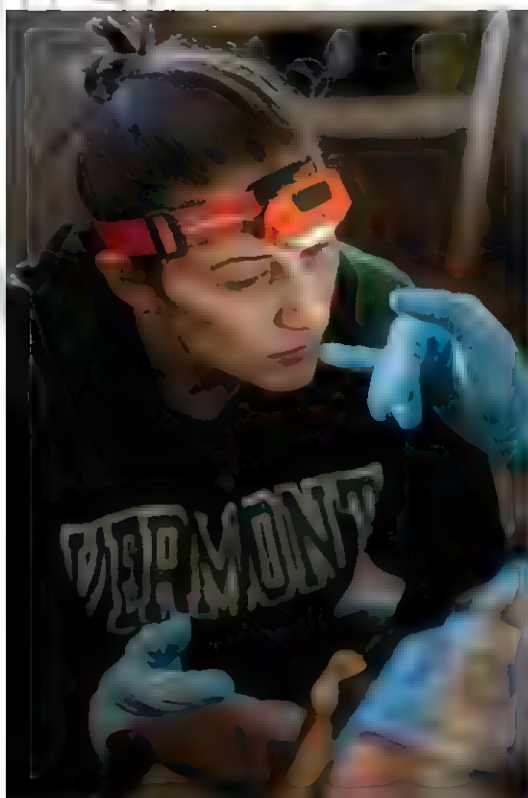
"Every species teaches us lessons on how  
we're supposed to live together," said Frankie  
Myers, the Yurok's vice chairman. Just as be-  
avers design their own environment, Myers  
said, Native people are charged with actively  
restoring nature to ensure its flourishing. "We  
do this work to restore our fisheries, restore  
beaver, because this is our place, right? We  
belong to this place."

*This page, top right:* The incisors embedded in this beaver skull show the telltale orange tint of beaver teeth. Iron in their enamel leads to the rusty coloration.

*Bottom right:* The beaver's distinctive tail operates like a rudder when swimming. It also functions as a fat-storage unit, providing energy reserves during the lean winter months.

*Bottom left:* Wildlife biologist Molly Alves processes a beaver that had been causing problems for landowners in Washington State. After being weighed and tagged, the animal was moved to a new location where it could thrive.

*Opposite page:* With its chisel-like teeth, a beaver can fell a tree in a matter of hours. The animals eat the bark and use the wood to build lodges and dams.



KHOLOD E D (LEFT); RONAN DONOVAN (RIGHT)



**T**HE FUTURE is liable to change for beavers. For one thing, they're expanding their range.

As climate change warms the Arctic, plucky beavers have followed onto willow-dotted tundra. In New York City, beavers have recolonized the Bronx River and Staten Island; in Seattle, they occupy 86 percent of suitable habitat. Considering the animals were once on extinction's doorstep, beavers have made a spectacular recovery, yet they're still at a sad fraction of their historic numbers—particularly in western states that need them most. Environmental laws like the Endangered Species Act prevent scarce animals from going extinct, but beavers pose a different challenge: How do we help an animal that's already fairly common become truly abundant?

Perhaps it starts with figuring out where they are—and aren't. The ultimate testament to beavers' influence may be that you can study their architecture from space. Engineers at Google have recently trained a machine-learning program, dubbed EEAGER, to identify the distinct appearance of ponds and dams in satellite imagery; California's wildlife department is using the algorithm to count its beavers and guide restoration. A similar effort, the Colorado Beaver Activity Mapper, has already roughly counted the Centennial State's beaver ponds (the tally: around 80,000). According to Sarah Marshall, the ecologist who led the Colorado program's development, getting a handle on beaver distributions could allow wildlife managers to preemptively address potential clashes with farmers and ranchers or pinpoint spots where beaver dam analogs and relocations will have the biggest water-storage and firefighting benefits. "Comparing where beavers used to be with where they are today is a prescription for where to do large-scale restoration in Colorado," Marshall said.

On a recent spring day, I visited Birch Creek, a stream in southern Idaho that represents a different approach to re-beaver-

Beavers can be a nuisance when they bump up against human infrastructure. This beaver was held at a salmon hatchery on the Tulalip Reservation in northwest Washington before it was released in the Skykomish watershed.

I walked upstream with Jay Wilde, a rancher who sported a battered cowboy hat and a drooping mustache. Every 60 feet or so, Birch Creek was stapled by another dam—some 80 feet long, some 10 feet high, some that formed staircases of mirrored, acre-wide lakes. Lobes of water shot onto the floodplain, single channels split into twisted strands, and beaver-dug canals spiderwebbed everywhere. A few neglected grass-covered dams melted into the landscape. It was glorious chaos, a mess of water and wood that scarcely resembled a discrete stream.

This was a recent transformation. Wilde had grown up along Birch Creek, which supported his family's homestead. By the late 1990s, though, the stream had dwindled to a pitiful trickle that would dry up



KHOLOD F.D.



by the Fourth of July. Birch Creek had lost its beavers, Wilde realized, and he resolved to bring them back. After two failed relocations, he contacted Utah State's Wheaton, the nearest beaver expert, whose crew built 26 beaver dam analogs in the creek between 2014 and 2017. The human-made dams created ponds in which subsequent reintroduced beavers could evade predators and focus their own damming. By the time I visited, more than 200 beaver-built dams spanned Birch Creek and its tributaries, and native cutthroat trout populations had grown more than tenfold. Better yet, the creek was again staying wet deep into summer, as water seeped from the saturated floodplain as though from a squeezed sponge. "We've gained 40 days of flow," Wilde

said, his drawl tinged with wonder.

Beavers, researchers sometimes point out, are critical infrastructure: builders of firebreaks and reservoirs and stormwater catchments. But they're also beings with their own wills, desires, and volition. Near my tour's end, a beaver popped up in one pond, head raised and ears pricked. "I had to train him all winter to do that," Wilde cracked—a joke that was funny precisely because beavers, for all their benefits to humanity, serve no master. The rodent swam to and fro, assessing us. Then, with a resounding *kerplunk*, he thwacked his tail against the surface, roiling the pond and raising a shower of droplets. By the time the tumult settled, he was gone, gliding invisibly through the watery world he had created. □





A century of smelting and logging near Anaconda, Montana, left the headwaters of the Columbia River Basin scarred and barren. Beaver dams on Mill Creek slowed the flow of water and allowed toxic pollutants to settle, improving downstream water quality.

ROMAN BONOVAN



## WHY YOUR DOG LOOKS LIKE YOU

New research confirms your long-simmering suspicion  
that dogs resemble their owners—and even act like them too.

*Words by* TARA LAW

*Photographs by* GERRARD GETTINGS



Hope (Afghan hound) and Henry

→ **WHEN I WALKED INTO** the ring at the Pennington Day dog show's Look-Alike Contest in suburban New Jersey in the mid-1990s, I was brimming with confidence. And why wouldn't I be? Soccer, my buff-colored cocker spaniel puppy, had long floppy ears—the perfect complement to my wavy

blond bob. We stormed to victory.

For the next few years, Soccer and I competed at Pennington Day in an array of matching outfits. We scored similar results, racking up a row of blue ribbons. I have not succeeded at anything as consistently since.



At this point it's a cliché: Lots of people look like their dogs. It turns out that there is actual science to support the stereotype. A recent review of 15 studies from around the globe suggests that people and their pets look and act similar. In several of the experiments, volunteers were asked to match pictures of dogs and their owners—and they scored higher than they would have just by chance. In one study, participants successfully inferred whether dogs were matched with the correct owners despite being able to see only the dogs' or owners' eyes. Another found that women often preferred dogs with ears similar in length to their hair.

So, what gives? A blend of benign narcissism, seemingly: Experts suspect people pick dogs that look like them or reflect them in some way. I imagine when I was young, my parents subconsciously chose our pet, Soccer, as she looked a bit like a canine version of their child.

Perhaps even more strikingly, the review also showed that dogs and owners share similar personality traits, especially in the cases of extraversion (the term psychologists use for extroversion) and neuroticism, and that their temperaments appear to grow more alike as the years pass. It offers different theories for why this might be the case. One idea is that owners could be drawn to dogs that are like them to begin with. Another holds that over time the pair may regulate each other's emotions, reinforce each other's behavior, or learn by observing and imitating one another.

After all, the relationships we build with our dogs can be some of the longest and most meaningful of our lives. "It resembles the way we also look for our partners,"

says review leader Yana Bender, a doctoral researcher in the DogStudies research group at the Max Planck Institute of Geanthropology in Jena, Germany. Dogs and their owners, she points out, share "a very close relationship ... comparable to many human relationships."

Authors of the review, published in the journal *Personality and Individual Differences*, noted several limitations to their research, such as the relatively small number of dogs and owners included in the studies. Many of the owners who volunteered to participate in the studies also had purebred dogs, and scientists need additional data on mixed-breed canines, which are more common worldwide.

Owner bias plays a role too. Even with standardized methods for assessing dogs' personalities, different researchers use varying concepts, and it can be just as hard to think about your own pet objectively as it is with your human family. (Who's the goodest boy? You are!) Ways researchers can address this bias? Using established questionnaires and asking owners more clear-cut questions about how their dogs act in certain situations, rather than asking them to weigh in on Fido's goodness.

The influence humans have on their dogs comes as no surprise to Borbála Turcsán, who studies dog behavior at Eötvös Loránd University's Faculty of Science, in Budapest, Hungary. She estimates that while about a third of a dog's personality is genetic, the remaining two-thirds is influenced by its environment—which means that if your dog has been with you from puppyhood, you occupy a place of enormous influence in its world. Dogs are also primed to trust their owners, because tens of thousands of years of domestication made them deeply attached to us. Like parents raising a child, pet owners can have a powerful influence over their dogs, Turcsán explains. For instance, "if there is a truck coming and it's

*Top*  
Archer (West Highland white terrier and pug) and Steven

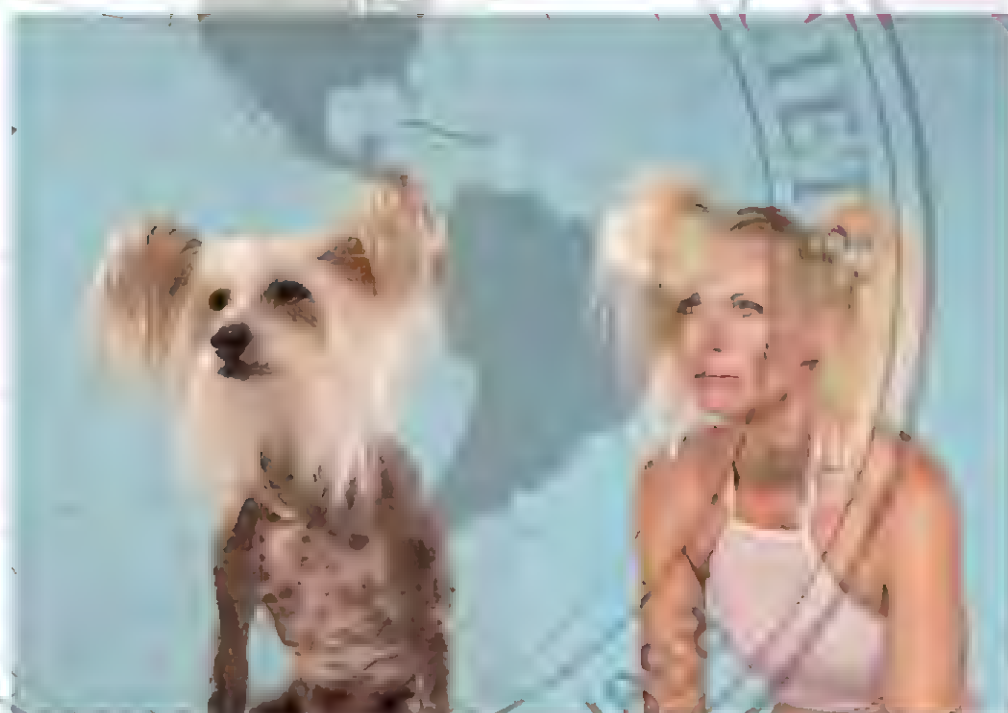
*Bottom*  
Reggie (chow chow) and Monica



very loud, then the dog will look back at the owner. If the owner doesn't care, then the dog will learn not to care," she says.

Bender hopes her study will help people build a deeper, more nuanced understanding of dogs, particularly those like search and rescue, police, and service animals that work in roles vital to public safety.

Not long ago, my husband and I adopted Milo, a mixed-breed pup that loves playing fetch and taking daily walks. We aren't quite the lock to win look-alike contests the way Soccer and I were, though he does have short tan ears—not far off from my current hairstyle. (Maybe that influenced why my husband and I picked him after scrolling



through several hundred photos of dogs at shelters and nonprofits all over Los Angeles.)

But even if I grow my hair long or dye it another color, I'll be mindful that the way I treat Milo can have a profound effect on him—just as his behavior can affect mine. To a point, of course: However he acts, he'll always be my goodest boy. □

*Top row, left to right*  
Rupert (Irish terrier) and Josh; Pixie (cocker spaniel) and Pete; Buddy (bichon frise) and Jessica

*Bottom row, left to right*  
Ralph (puli) and Emma; Harper (schnoodle) and Benji; Caspar (Chinese crested) and Charlotte

THE FUTURE OF FASHION IS



# FARM TO CLOSET



Thomas S. Johnston, Ph.D., is a Distinguished  
University Professor at the University of  
Michigan, Ann Arbor, Michigan.

WILEY-INTERSCIENCE  
FIRST EDITION BY ARTHUR H. HALL



**O**N A DAMP DECEMBER morning in the mountainous district of Ambarawa in Central Java, a woman in an inky black sleeveless vest and gathered skirt balances herself on the back of a motorbike that carries her through a small village, past houses adorned with tropical plants and birdcages, and into a forest. The land here, some 300 miles east of Indonesia's capital of Jakarta, brims with shrubs and trees that grow a variety of crops, including cassava and coffee. But it's the forest floor that's brought Denica Riadini-Flesch, 34, to this corner of her home country. Under the shade of banana, papaya, and coconut trees, she's trying to seed a revolution—in the form of hundreds of vibrant indigo plants, all casting a glossy viridescence across the soil.


Riadini-Flesch is the founder of SukkhaCitta, a fashion brand that partners with hundreds of Indonesian farmers and artisans on Java and in neighboring Bali, Flores, and West Timor. And it's her company that inspired the success of this burgeoning crop. Indigo comes in many varieties, but one commonly used in Ambarawa needs profuse sunlight. Riadini-Flesch realized that boosting growth would require cutting down trees. Instead, she offered the farmers an alternative: a hardy varietal called Assam indigo, which flourishes in the shade. Today the forest is awash with indigo that brings vital income into the community while fueling a kaleidoscope of colorful dyes for SukkhaCitta's clothing.

This includes the very garments Riadini-Flesch is wearing, which achieved their botanical black hue after being dipped

Fashion brand SukkhaCitta offers an alternative to factory-made clothing by working with regenerative cotton farmers like Ely Yulianti (top left) and Alintehn (bottom right) and artisans like Agustin Ningrum (top right) and Muntiani (bottom left).

MAP: CHRISTINE FELDZ, ENZ, NGM STAFF





SukkhaCitta founder Denica Riadini-Fleisch stands amid a crop of indigo in a forest in Central Java. The ancient pigment used in fabric dyeing is often grown in open fields. But SukkhaCitta encourages farmers to plant a varietal that requires less sunlight, to prevent deforestation.



into fermented indigo leaves 30 times. Such a meticulous process is at the heart of Sukkha-Citta's environmentally responsible and ethical fashion brand. The Kapas *kebaya* vest she's wearing retails for \$320, and the Angkasa Constellation *kain*, a fabric she ties into a sarong, sells for about \$500 — pricing that reflects the workmanship of each garment. As she stands among the trees, Riadini-Flesch exudes a sense of awe that she hopes to convey to her customers. "This," she says excitedly, "is a fashion forest."

Indigo is just one ingredient in Sukkha-Citta's radically transparent supply chain. Every piece of fabric in the brand's farm-to-closet collection is crafted out of 100 percent plants, from traceable natural fibers to regeneratively grown plant dyes. Cotton fibers are

A farmer (right) examines a harvest of cotton. SukkhaCitta supports the Indigenous technique of *tumpang sari*, wherein seedlings (below) are planted alongside crops like peanuts and chilis that help replenish the soil and repel pests.





hand-spun and woven on manual looms. Fabrics are decorated by Indigenous artisans practicing an intricate hand-drawn wax technique called batik before being dipped into vats of color, dried in the sun, and finally cut and stitched into clothing. The entire process, from seed to garment, takes about 60 to 180 days. Once completed, clothing is sent to SukkhaCitta's flagship store in Jakarta, marketed online, or sold at select boutiques in Singapore and New York, where clients are increasingly inclined to put their dollars toward an elegant dress or a pair of pants designed by brands that prioritize their social and environmental impact on the world.

The so-called slow-fashion movement has arisen in direct opposition to the values of fast fashion, the prevailing, factory-led process that's rife with excess and waste. Many of today's clothingmakers contribute to a \$100 billion-plus industry of cheap polyester T-shirts and spandex leggings, which comes at the cost of both exploited workers and the environment. In

## CRAFT AND FARMING WERE DEEPLY ROOTED IN VILLAGE LIFE; THEY JUST NEEDED TO BE RESTORED.

Indonesia, the Citarum River, a main source of drinking water and irrigation, is contaminated by toxic chemicals dumped into the waterway by the textile factories that line its banks. And the global impact stretches farther: From the Atacama Desert in northern Chile to a landfill outside of Ghana's capital of Accra, mountains of discarded clothes pile higher each year.

Riadini-Flesch believes that empowering consumers with knowledge about how their clothes are made—be it the plants that color them or the artisans who stitch them—will lead to a deeper relationship with what they wear, a stronger appreciation for both the craft and the product, and a realization that the choices we make as consumers directly affect people and the planet. She's already drawn an impressive roster of influential supporters. Rock musician Chris Martin from Coldplay, National Geographic Explorer at Large and oceanographer



Farmer Kasmini (right) spins raw cotton to make thread for weaving fabric. She's supported by fellow farmers Tasmina (left) and Karmini (center), first stretching and fluffing cotton by hand while Karmini's grandson watches.





In Central Java, palm sugar farmer Maat scales a tree to harvest the sap, a critical ingredient in SukkhaCitta's all-natural dyeing process. Sugar from the sap is used as an activator for the indigo, helping create rich hues for the company's fabrics.



Sylvia Earle, and celebrated cellist Yo-Yo Ma have been spotted in SukkhaCitta garments. “Denica’s journey is testament to the best kind of cultural thinking,” says Ma, who has kept in touch with the founder, “powered by a willingness to put in deep work with head, heart, and hands.”


SukkhaCitta is not the first brand to provide an alternative blueprint to how fashion is created. And it’s met a fundamental truth head-on: Clothes made with care and intention are going to be relatively more expensive than the alternatives. But Riadini-Flesch believes that if shoppers understand the value of what they’re paying for, they’ll realize that cheap garments bear a far greater cost. “Clothes won’t change the world, but the people wearing them will,” she says. Her journey started with thinking about how she could use her own knowledge as a bridge to uplift others and replenish the planet.

**W**HILE INDONESIA HAS made strides in reducing poverty, 9 percent of the population still struggles to make a living wage. That’s roughly 24 million people, many of whom live in rural villages. Growing up in Jakarta, Riadini-Flesch experienced the country’s deeply rooted issues with inequality and studied developmental economics in college. After a stint working at the World Bank, she gained her most sobering understanding of what that truth looks like when she began traveling the countryside in 2013.

Riadini-Flesch knew nothing about fashion, but one day she met three batik artisans in a village on the outskirts of Tuban, in East Java. The women told her that they had learned the ancient craft from their mothers, who had used natural dyes to color their fabrics. But their tradition was at risk. With limited resources, the artisans had switched to cheaper and more readily available chemical dyes that burned their lungs, yet even then they could not compete with the speed of factory-printed textiles. All were mothers, or *ibus*, who worried about feeding their families.

Until then, Riadini-Flesch had never thought about how clothing was created. “It made me realize that without knowing it, I was part of the problem,” she says.

In the months that followed, Riadini-Flesch saw other problems in the modern fashion supply chain, which affected not only the artisans but also farmers, who had abandoned cotton growing for monoculture crops like corn, thereby degrading the health of the soil, plants, and wildlife that thrived with agricultural diversity. Both of these age-old practices, craft and



At a craft school funded by Sukkha-Citta, practitioners make indigo dye using passed-down techniques, fermenting the leaves in a concrete tub before mixing the water with limestone to produce a thick, bubbly liquid.



Indigo farmer Muhammad Khoe-rul Uman holds up a fresh harvest of Assam indigo. As with the regeneratively farmed cotton, the indigo is planted alongside crops like coffee and cassava to keep the soil and the ecosystem healthy.

farming, were deeply rooted in village life; they just needed to be restored. Slow fashion, she realized, could create a new vehicle for change.

Early on, the *ibus* were wary of Riadini-Flesch because of stark class divisions in Indonesian society. Although she had only \$2,000 to invest, she put that money into paying the batik artisans a living wage, which allowed her to create her first sample: a bandanna she called *Kupu*, or butterfly. By 2019, three years after incorporating, the company had drawn enough interest from residents near Tuban to open its first craft school with the Rumah SukkhaCitta Foundation, which is funded by the company's profits, donations, grants, and entrepreneurship awards from nonprofits and aid groups.

The schools provide workshops where artisans can teach batik to younger generations and farmers can learn about regenerative ways to plant cotton. Villagers are now leveraging an Indigenous technique known locally as *tumpang sari*, which prioritizes the cultivation of multiple plants together, allowing them to nourish each other. Cotton is planted alongside corn, which provides shade; chilis help control pests; and peanuts add nitrogen to the soil. The approach allows rural Indonesians to grow cotton for SukkhaCitta while providing more food for their families and additional vegetables or nuts that can be sold for extra income.

Now, Riadini-Flesch and the *ibus* embrace each other as family. On a recent visit, she bantered with the women as they dipped their tools, or *tjantings*, into bowls of hot wax and traced motifs onto fabric. A sense of trust enveloped the group. Reclaiming their craft has allowed the women to restore their identity. "It isn't blood that flows through our veins," one of the *ibus* once told Riadini-Flesch. "It's hot wax."

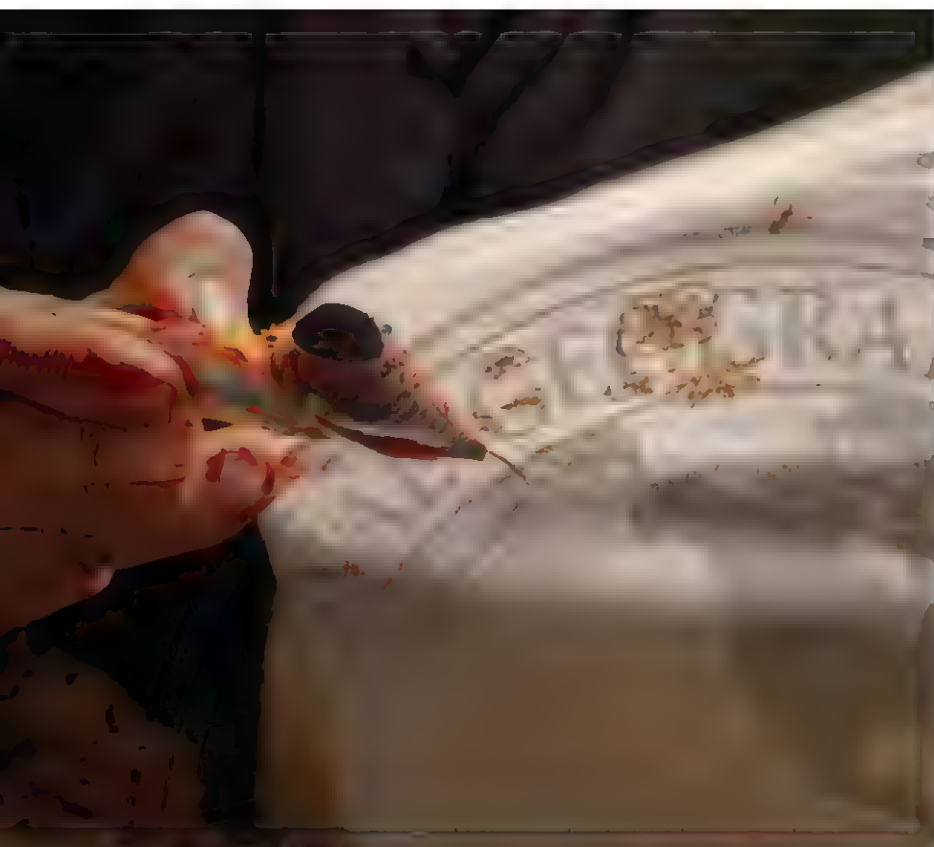
From the start, SukkhaCitta has worked to raise the standard of living for the people in its partner villages. That includes using some profits to create grants for villagers who are interested in purchasing farmland. The women are also trained to reappraise both the social and monetary value of their work. Rather than negotiate payment after their labor is complete, as many had in the past, they are taught to track the time it takes them to complete a design or even a cotton harvest. SukkhaCitta then uses that number to calculate a higher wage, increasing their income significantly.

Initiatives like these have established Riadini-Flesch as a role model for other entrepreneurs and helped boost the company's following on social media. SukkhaCitta's clothes have been featured in *Vogue's* Singapore edition, and sales are now increasing by 30 to 40 percent annually, she says, allowing the company to bring economic opportunities to the villagers. Linna Setyowati, 32, received a grant from SukkhaCitta to purchase a





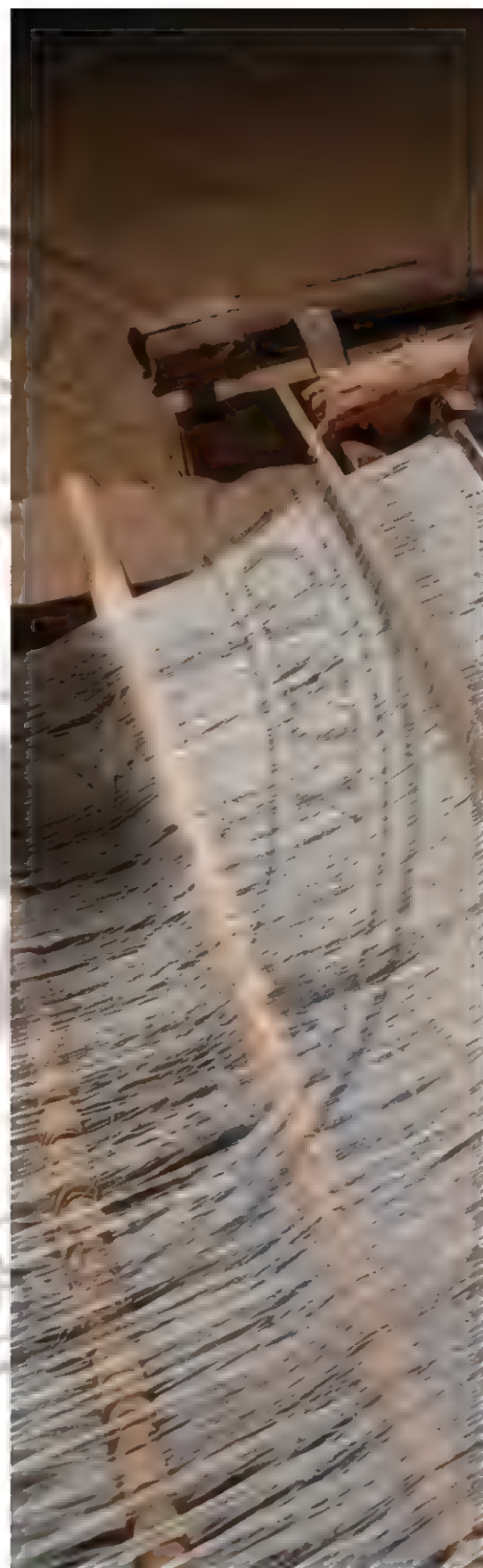
In Central Java, one of SukkhaCitta's partner villages emerges from the fog while two of the island's volcanoes loom beyond it. Since launching in 2016, SukkhaCitta has partnered with 11 villages across four islands, bringing more prosperity to rural areas.

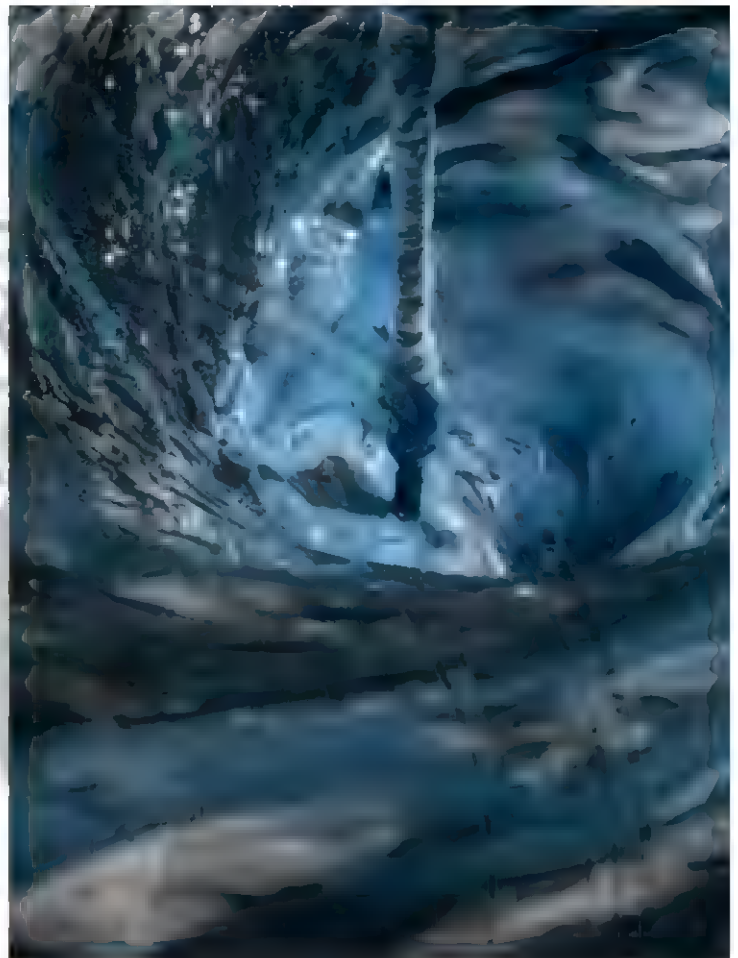


two-and-a-half-acre plot of land, which she nourished back to health after its degradation by chemical weedkillers and fertilizers. She's now following the principles of tumpang sari as she waits for her cotton bolls to be ready for harvest. The land is "fresher," she says. "It's healthy."

And most important, it's hers.

**A**CROSS THE GLOBE, other entrepreneurs are developing their own slow-fashion enterprises. The offerings range from ethically sourced alpaca sweaters made in Peru to vegan leather derived from Sicilian cacti and oranges. Angelina Jolie recently opened a workshop in Manhattan, where clients can remake their own garments into new one-of-a-kind designs. For her part, Riadini-Flesch admires the French brand Veja, which makes sneakers out of organic cotton and Amazonian rubber. Like Veja, which rebranded the shopping frenzy of Black Friday to "Repair Friday," SukkhaCitta encourages customers to return their clothing for mending or re-dyeing, and





From indigo dyeing (above) and cotton weaving (center) to the art of batik (left), in which artisans use hot wax to draw intricate designs on the fabric, SukkhaCitta is promoting the authentic stories behind its clothes.

the brand offers a lifetime repair guarantee.

As Riadini-Flesch sees it, these kinds of ventures offer new ways for people to understand that there's an alternative to extractive fashion. "I never consider ourselves to have competitors," she says. "It's about changing the paradigm."

One of her latest efforts transpired in November 2024, when SukkhaCitta opened a pop-up boutique at an upscale mall, its second location in Jakarta. While the garments for sale range from an indigo shirt decorated with



The waste from many clothing manufacturers' synthetic dyes has poisoned some of Indonesia's rivers. SukkhaCitta's dyeing process offers a natural alternative, for workers and the environment.



Each SukkhaCitta piece takes between 60 and 180 days to go from cotton planting to the brand's flagship store in Jakarta. The clothing is also sold online and at boutiques in New York and Singapore.

geometric stars to a yellow dress whose color is derived from Java's golden *jelawe* fruit, one of the store's primary purposes is to showcase a traveling exhibition about SukkhaCitta's supply chain. Glass containers hold soil from the villagers' farms. The life cycle of a cotton plant is on display. And a video features interviews with the *ibus*, showing the invisible love and labor behind each product. One of the most striking presentations explains how the brand's garments are specifically made to return to the earth rather than wind up in landfills: A display case lined with soil shows a single cut of SukkhaCitta cotton as it degrades progressively over the course of six weeks, ultimately turning into tiny fragments that can be used in compost. Riadini-Flesch hopes to take the exhibition international, sharing it at more pop-up stores.

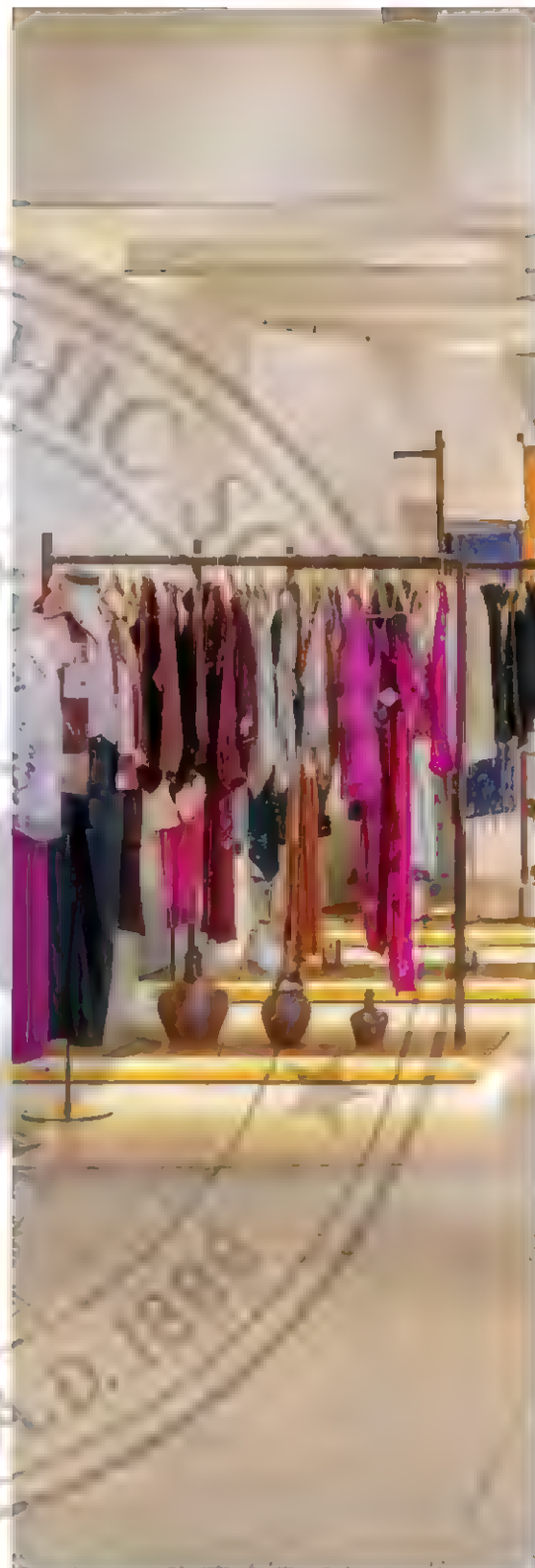
In part to inspire other brands, she's also tracking how well her practices are working by earning fair-labor and environmental-impact certifications from watchdog groups like Nest, a nonprofit that verifies ethical work standards, and the Science Based Targets initiative, a climate-action organization that measures greenhouse gas emissions. Recently, SukkhaCitta became the first fashion company in Indonesia to secure B Corp certification as a business that is committed to transparency and accountability. The brand's approach signals a remarkable mix of business acumen and social purpose by not just scaling for profit but also "scaling impact," says Sarah Schwimmer, who runs B Lab Global, the nonprofit behind the certification. "She is demonstrating a new way forward," Schwimmer says.

Over the past four years, the brand has opened four additional craft schools, launched a spin-off materials platform so that others can source SukkhaCitta's regenerative materials, and established partnerships with 11 villages. The company plans to cap rather than grow that number, so it can boost the resources it provides to each location. So far, SukkhaCitta has helped communities transform roughly 118 acres of previously commercial farmland, which has had a direct impact on more than 1,500 lives there. By 2030, it expects to ramp up to more than 2,400 acres and reach up to 10,000 people.

One thing SukkhaCitta will not do is follow traditional seasonal fashion calendars or overexert the artisans or the lands it manages. If demand for a product skyrockets and the elements won't allow it, the company will simply be sold out.

"You cannot have infinite growth on a finite planet," Riadini-Flesch says.

It is wisdom shared by the *ibus*, who also taught Riadini-Flesch a philosophy that inspires her every day: "*Urip Iku Urup*." We live to bring light. □





SukkhaCitta, which counts Coldplay's Chris Martin and cellist Yo-Yo Ma among its supporters, has steadily grown its sales in recent years. After these clothes leave the showroom, they can eventually return to the earth. Riadini-Flesch has ensured that her fashion line is biodegradable.



From the fields to the shopping mall, SukkhaCitta stands among an increasing number of brands to draw up and follow a blueprint that keeps cotton farmers like Karmini, Tasminas, Parti, and Kasmini at the forefront of their business model.



EXPLORERS OF THE YEAR

PABLO 'POPI'  
GARCÍA  
BORBOROGLU  
*and*  
BERTIE  
GREGORY

→ **AS A BOY** growing up in Argentina's Buenos Aires Province, Pablo "Popi" García Borboroglu was enchanted by his grandmother's tales of her youthful visits to the teeming penguin colonies of Argentine Patagonia. He was a 19-year-old tour guide when he first glimpsed one, and it dawned on him then how important it was to share with others his sense of awe, inspiring them to protect penguins and their habitats.

A hemisphere away, Bertie Gregory came to a similar realization as a teenage wildlife photographer roaming the English countryside. Today, at 31, he's an accomplished wildlife filmmaker and lead storyteller behind the new National Geographic series *Secrets of the Penguins*—on which he worked with Borboroglu, now a marine biologist and founder and president of the Global Penguin Society. For their efforts, Borboroglu and Gregory have been named the 2025 Rolex National Geographic Explorers of the Year.

"Popi García Borboroglu and Bertie Gregory exemplify the power of collaboration in exploration," says National Geographic Society CEO Jill Tiefenthaler. "By uniting groundbreaking conservation science with masterful storytelling, they not only deepen our understanding of penguins but galvanize global action to protect them."

Borboroglu's initiatives to create protected





areas for penguins have helped conserve some 32 million acres of habitat, on land and at sea. Now 55, he takes inspiration from the birds' resilience—the way they swim hundreds or even thousands of miles for food, avoid predators and pollution, and survive in environments increasingly affected by climate change. “When you see penguins making that big effort,” he reflects, “you say, How can I give up?”

Borboroglu and Gregory shared a spotlight in last month's “Secrets of the Penguins” cover story (and there's more on their adventures with penguins at [nationalgeographic.com](http://nationalgeographic.com)). Being recognized as an Explorer of the Year alongside his filmmaker friend, Borboroglu says, is “fantastic...a great combination of different kinds of explorers and expertise.”

**‘WHEN YOU SEE PENGUINS MAKING THAT BIG EFFORT,’ BORBOROGLU REFLECTS, ‘YOU SAY, HOW CAN I GIVE UP?’**

At first, Gregory says, he was hesitant to make a documentary about penguins. The Emmy-winning host of the Disney+ series *Animals Up Close*, who has shot for iconic series like *Planet Earth* and *Frozen Planet*, knew that filming in penguins' harsh habitats would be tough—and worried the species was already plenty documented. “If you're going to make a series called *Secrets of the Penguins*,” he says, “you've got to show people something they've never seen before.”

But Gregory embraced the challenge. To film one of the series' three episodes, he camped for more than two months near an emperor penguin colony in Antarctica's Atka Bay. He was documenting a critical phase in a penguin's life cycle, when juveniles, abandoned by their parents, are

left to figure out how to become a “proper adult penguin,” getting themselves to the ocean to swim and hunt.

Gregory succeeded spectacularly in capturing behaviors never before filmed, including footage of hundreds of young emperor penguins entering the sea by “BASE jumping” off a 50-foot cliff. “I really think it's going to blow people's minds,” he says. “I thought I knew what penguins' limits were. I was wrong.” —RENE EBERSOLE

Borboroglu (above) has been an Explorer since receiving the National Geographic/Buffett Award for Leadership in Conservation in 2018. Gregory became an Explorer in 2015 with a grant to document Vancouver Island's wolves.

PHOTOS: ANTHONY PYPER (BORBOROGLU); ZUBIN SAROSH (GREGORY)

*Secrets of the Penguins is now streaming on Disney+. Check local listings.*



## EXPEDITIONS

➔ **ON SAFARI**, there's no telling what might cross your path—and in South Africa's Greater Kruger area, rhinos have right-of-way. But there's a lot more than wildlife-watching to the newest land itinerary from National Geographic Expeditions. The nine-day Southern Africa: Living History and Legendary Species journey begins with a visit to a vibrant neighborhood of Cape Town and a walk in Table Mountain National Park. After taking in turbulent seascapes at the Cape of Good Hope and a colony of

endangered African penguins, guests head to Sabi Sabi Private Game Reserve, bordering Kruger National Park and home to some 400 species of wildlife. A bush lodge is base camp for three days of safaris and talks with trackers, rangers, and National Geographic experts. The trip ends in Zambia, at the foot of Victoria Falls, near where elders of the Leya people share their traditions during a village tour. That rhino encounter? Might not even make your top-five list. *Learn more at [nationalgeographic.com/expeditions](http://nationalgeographic.com/expeditions).*

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## NEWSSTANDS



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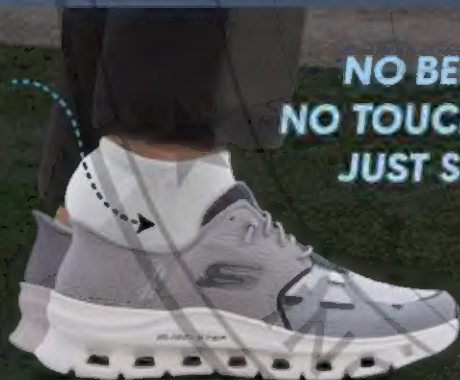
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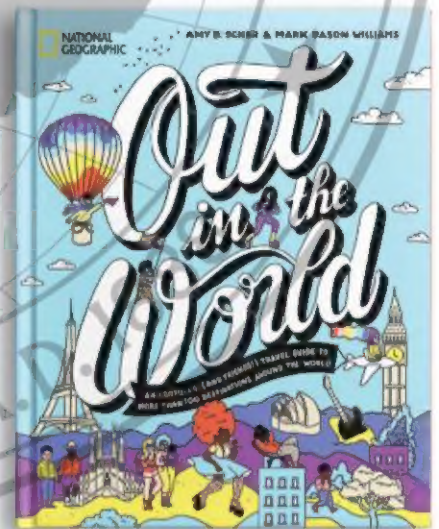
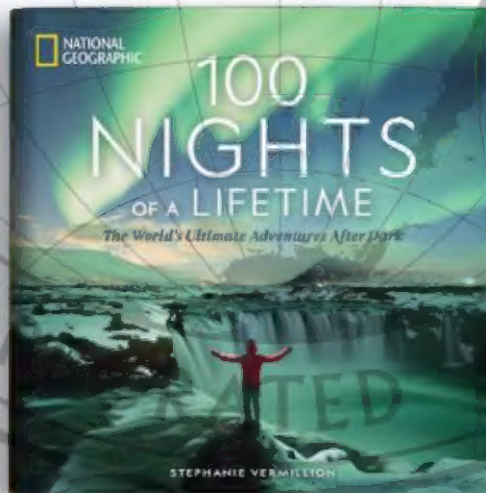
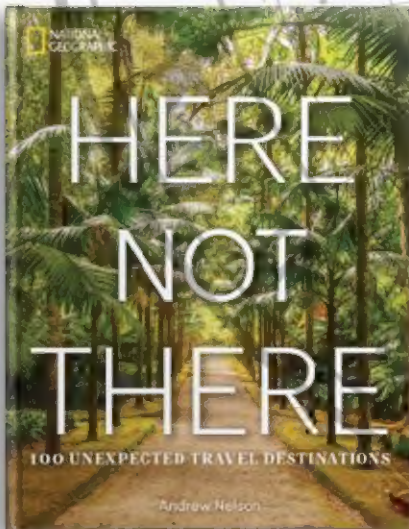
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